# AN EVENT RELATED BRAIN POTENTIAL STUDY OF LANGUAGE PROCESSING IN KANNADA-ENGLISH BILINGUAL APHASICS

**Thesis submitted to the University of Mysore**

**for the award of**

**Doctor of Philosophy (Ph.D)**

**in**

**Speech-Language Pathology**

**By**

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**July 2014**

# CERTIFICATE

This is to certify that the thesis entitled **"An Event Related Brain Potential Study of Language Processing in Kannada-English Bilingual Aphasics"** submitted by Mr. Sunil Kumar. Ravi for the degree of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysore was carried out at the All India Institute of Speech and Hearing, Mysore.

Place: Mysore

Date: 11th, July, 2014

**DIRECTOR**

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Mysore-570006

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Place: Mysore

Date: $11^{th}$, July, 2014

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## DECLARATION

I declare that this thesis entitled **"An Event Related Brain Potential Study of Language Processing in Kannada-English Bilingual Aphasics"** which is submitted for the award of the degree of Doctor of Philosophy (Speech-Language Pathology) to the University of Mysore, is the result of original work carried out by me at the All India Institute of Speech and Hearing, Mysore, under the supervision of Dr. Shyamala. K. C, Professor of Language Pathology, Department of Speech Language Pathology, All India Institute of Speech and Hearing, Mysore. I further declare that the results of this work have not been previously submitted for any degree.

Place: Mysore **Sunil Kumar. Ravi**

Date: 11th, July, 2014

## Abstract

***Introduction:*** The advancement in technology such as magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI) and electrophysiological measures has helped researchers and clinicians in understanding of brain and language relationship in neurolinguistics domain in a better way. However, the organization of two languages in bilinguals' brain is still unclear as the results of the studies are contradicting each other as many variables and factors are involved in bilingualism. The better understanding of normal organization of languages in bilinguals will in turn improve the clinical services to persons with aphasia, dementia, and so on. Individuals with aphasia do exhibit several language deficits in syntactic and semantic processing. Event related potentials (ERPs) are found to be very useful in understanding the temporal course of language processing in both typical individuals and also in clinical population. ERPs have been widely used in language processing studies especially in semantic and syntactic processing with N400 and P600 potentials. The understanding of language processing in mono, bi/multilinguals will help speech language pathologists to provide better speech and language therapy to clinical population. Although, many studies have been carried out to study the language processing in several languages, there are no studies to explore the language processing in Indian languages and Indian bilingualism. Hence, there is a strong need to understand the similarities and differences in processing of distinct languages in typical bilinguals and also in bilingual participants with aphasia.

***Aim:*** The present study is aimed at investigating the cortical representations and neurofunctional mechanisms of language (syntactic and semantic components) processing of Kannada (L1) and English (L2) languages in persons with bilingual aphasia and normal/typical bilingual individuals.

***Method:*** The study consisted of 20 Kannada-English bilingual participants with aphasia (Group I) and 20 typical/normal Kannada-English bilingual participants (Group II). All the participants were assessed for behavioral measures such as accuracy and reaction time measures and electrophysiological measures (N400 and P600 components) during semantic and syntactic judgment tasks in Kannada (L1) and English (L2). A total of 34 electrodes were used to record event related potentials in both the groups using Compumedics Neuroscan Inc system during semantic and syntactic judgment task of 150 sentences in each language. EEG data was analyzed at electrode level, scalp region level

and hemispheric levels and within group and between group comparisons were made to understand the language processing in bilingual persons with aphasia and typical bilinguals.

***Results and Discussion:*** Results of ERP data of clinical group (group I) showed presence of N400 component for semantically violated sentences with broad scalp distribution over left and right hemispheres in both L1 and L2. Similarly, syntactic violations in both L1 and L2 resulted in P600 component over both left and right hemispheres with major activation in centro-parietal regions indicating involvement of both left and right hemispheres during processing of semantic and syntactic aspects in both L1 and L2. Results of ERP data of typical participants (group II) revealed presence of N400 effect for semantically incorrect sentences which was broadly distributed in left hemisphere for L1 and distributed in both left and right hemispheres for L2 at electrode level, hemispheric level, and scalp region. N400 was observed majorly at left central and posterior scalp regions for L1. While in L2, N400 component was present at left centro-parietal and right posterior regions. Syntactic violations in both L1 and L2 resulted in P600 component in typical group with greater activation levels in left and central regions in L1 and greater activation levels were seen in both right and left hemispheres indicating role of right hemisphere in processing L2 in typical individuals. Comparisons between typical and clinical groups also revealed significant differences in both L1 and L2 for semantic and syntactic violations at electrode level, hemispheric and scalp region levels.

***Conclusions:*** the present study revealed significant differences for language processing between clinical and typical groups over electrophysiological measurements and also over behavioural measurements. The present study also revealed that electrophysiological measures can be a valid tool in assessing language impairments in clinical population. However, more studies are required to explore the effect of various factors such as age of acquisition, proficiency levels on language processing in bilinguals. More studies in Indian context using ERPs on typical and clinical populations will help in validating the ERPs as tool for assessment of language abilities in clinical population.

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# INTRODUCTION

## Language and Bilingualism

Language is the basis for any form of communication in this world and it plays a great part in our life. This language can be in variety of forms, including spoken, written, sign and body language. Bloom and Lahey (1978) have defined language as ‘a code, whereby ideas about the world are represented through a conventional system of arbitrary signals for communication”. This language can be used for both intrapersonal (one’s self) and interpersonal (between people) communication in social contexts to perform various kinds of communicative acts. Language acts as a medium to communicate our ideas, thoughts, needs to others. There are three major dimensions of language namely, *form (phonology, syntax & morphology), content (semantics)* and *use (pragmatics)* (Bloom, 1988). For any person to attain language competence, one must effectively integrate all the three dimensions of language (Bloom, 1988).  Normal children start acquiring language skills since their birth and continue throughout the life as adults and also they may learn new languages for various purposes. There are several prerequisite factors to language development and its use. These include anatomical, physiological, neurological, perceptual, cognitive and social factors.

Bloomfield (1935) defined bilingualism as “native-like control of two languages”. Another definition of bilingual given by Macnamara (1967a) as “anyone who possesses a minimal competence in any one of the four language skills, listening, speaking, reading and writing, in a language other than his mother tongue. Bilingual individuals use two different languages simultaneously for personal and social communication. This usage of two languages in different context as per the need puts more demand on their cognitive skills. The usage of two different languages has been shown to have larger impact on language and cognitive performance of the person (Bialystok, Craik, Green & Gollan, 2009)

In the process of globalization and change in educational systems, the globe becomes more interconnected and it is very evident that bilingual population is rising across the world. India has 22 constitutionally accepted languages with four languages having classical language status, while there are about 1652 languages / dialects spoken in and around the country. The major language families in India include Indo – Aryan (74.3%), Dravidian (23.9%), Austro – Asiatic (1.2%) and Tibeto – Burman (0.6%). Some languages have scripts while many do not have. As per the 2001 census of India, approximately 25% of the total population are bilinguals in India which is very high compared to that of 1991 census of India which reported only 9% of the total population is bilinguals in India. Crystal (1997) estimates bilingualism that includes English and another language represents about 235 million people worldwide and that two thirds of children in the world are grown-up in bilingual backgrounds. Major reasons for increase in bilingualism include immigration, or a national situation wherein the official language is different from the community language (e.g., India), or formal education in another language, etc.

**Brain and Language**

The cortex of the brain comprises of two hemispheres – left and right hemispheres. Although both the hemispheres contribute to language processing, left hemisphere is known to be dominant for the language functions in majority of individuals. Damage to either of the hemispheres, majorly to left hemisphere causes various types of language disorders in both children and adults. Aphasia is a language disorder that is caused by brain damage to the dominant hemisphere. The major cause for aphasia is cerebrovascular accidents (CVA) or stroke which accounts for 80%.

CVA or stroke is defined as "a sudden loss of brain function resulting from an interference with blood supply to the brain" (National Institute of Neurological Disorders and Stroke). Stroke is one of the major causes of death across globe and it is the cause of aphasia in around 80% of total aphasic patients. Sethi (2002) have estimated the prevalence of stroke in India as 203 per 1,00,000 population, amounting to a total of about 1 million cases.

Benson (1979) defined Aphasia as "loss or impairment of language caused by brain damage". Goodglass and Kaplan (1983) defined aphasia as "disturbance to any or all of the skill, associations and habits of spoken or written language, produced by injury to certain brain areas that are specialized for these functions". Language deficits in individuals with aphasia vary widely from person to person. These individuals may have deficits in phonology, syntax or lexical access or semantic errors, etc., apart from impairments in spontaneous speech, auditory comprehension, repetition, naming, reading and writing depending upon the site of lesion. These deficits also vary on severity levels depending upon the extent of brain damage.

Neurolinguistics, a subfield of linguistics, studies the role of brain mechanisms in language processing. Research work on understanding the relation of language and brain has began way back in 1861 with Paul Broca's study on an aphasic patient. Since then, many studies and research work have been done to get more insights into brain and language relationships. The initial research work done on brain and language relationships is majorly through case studies of aphasic patients. Later on with advancement of technology and invention of new instruments like ERP, PET, SPECT, fMRI techniques, the research has become much easier also providing much accurate information regarding the role of brain mechanisms in language processing. Neurolinguists and psycholinguists have used the above technology with behavioural tasks to study the functioning of brain during every aspect of language processing in both typical individuals and disordered population.

Given these demographics in Indian scenario on stroke and bilingualism, the number of individuals with bilingual aphasia is rising. The deficits/impairments seen in language aspects of bilingual aphasics are quite distinct from that of monolingual speakers. The same is applicable even in terms of recovery patterns, in which, bilingual individuals with aphasia demonstrate a variety of recovery patterns in their languages (Paradis, 1977).

**Sentence Processing**

Sentence processing involves a more complex mechanism compared to processing of words, as the listener or reader needs to identify the structures of a sentence and process them to understand the meaning of the whole sentence within few seconds. Few models such as the garden-path model (Frazier, 1978), and constraint-based satisfaction models of sentence parsing (MacDonald, 1994) have focused on explaining the strategies used in sentence interpretation. Garden-path model hypothesizes that the comprehension of sentences involves only computation of single syntactic analysis, whereas, constraint based theories assume that syntactic analysis is done based on all relevant information. The models of garden-path (Frazier, 1978) and constraint-based satisfaction (MacDonald, 1994) varieties majorly focused on parsing strategies in sentence comprehension. Several studies were carried out to explore the nature of parsing strategies involved in sentence comprehension using methods such as eye-tracking, accuracy, speed of processing, and event-related potential studies. However, in certain circumstances such as under accuracy and speed measures, participants may not notice ambiguity or mis-parse the sentences. The garden-path (Frazier, 1978) and constraint-based satisfaction (MacDonald, 1994) models do not explain the processing of some of the passive structures of language and some ambiguous sentences.

Individuals with aphasia do exhibit deficits in several language domains such as auditory comprehension, naming, fluency, reading and writing. Individuals with aphasia always have difficulty in comprehending both spoken and written sentences. Several studies have been carried out in the past to examine the language deficits in aphasia at word and sentence level in auditory mode (Caplan, Waters, DeDe, Michaud, & Reddy, 2007; Grodzinsky, 2000; Thompson & Choy, 2009). However, individuals with aphasia have also been found to be slow besides exhibiting difficulties in reading comprehension at sentence level. Reading comprehension is a complex phenomenon in which semantic, syntactic, and orthographical factors are integrated to accomplish the task. Sentence comprehension is a multifaceted process which requires quick and accurate access to the lexical system to retrieve and understand the semantic and syntactic information provided by the sentence. Thus, the speed of lexical activation or accuracy of lexical information (or lack of it) may contribute to the sentence comprehension impairments in individuals with aphasia (DeDe, 2012).

Several studies have been carried out in the past to explore the factors contributing to the sentence comprehension impairments in persons with aphasia (PWA). The speed of lexical activation is found to be one of the main factors contributing to the impaired sentence comprehension in persons with aphasia (Del Toro, 2000; Milberg & Blumstein, 1981; Thomson & Choy, 2009). It is also found that PWA exhibit incomplete access to word class information and are slow in integrating the words of sentence (Ter Keurs, Brown, & Hagoort, 2002; Thompson & Choy, 2009).

The present study aims to review the literature with respect to neurolinguistic and psycholinguistic issues of aphasia such as bi/multilinguals' sentence processing and physiological studies in aphasia extrapolating the information for the need, design and method in the present context. The present study also aims to understand neurophysiological mechanisms involved in language processing in persons with aphasia and also typical bilinguals.

# Chapter 2

# REVIEW OF LITERATURE

## 2.1. Bilingualism

The concept of bilingualism is quite old and several authors defined bilingualism in myriad of ways depending upon various factors involved in it. Webster's dictionary (1961) defined *bilingual* as "having or using two languages especially spoken with the fluency characteristic of a native speaker; a person using two languages especially habitually and with a control like that of a native speaker" and *bilingualism* as "the constant oral use of two languages". This definition is accepted widely in studies of bilingualism and this is considered as an elaboration of definition given by Bloomfield (1935) who defined bilingualism as "the native-like control of two languages". However, the above two definitions only explain the perfect bilinguals or balanced bilinguals but not other types of bilinguals. Hence, Macnamara (1967) defined *bilingual* as "anyone who possesses a minimal competence in any one of the four language skills, speaking, listening comprehension, reading and writing, in a language other than his mother tongue". These definitions which differ in competence levels from native-like to minimal proficiency in L2, pose a number of theoretical and methodological difficulties.

The above definitions were proposed only on the basis of proficiency level in two languages and ignored non-linguistic dimensions. Mohanty (1994) defined bilingualism only in view of social – communicative dimension, viz., "bilingual persons or communities are those with an ability to meet the communicative demands of the self and the society in their formal functioning in two or more languages in their interaction with the other speakers of any or all of these languages". Apart from the above definitions, there were other definitions which were proposed based on the specific characteristics of the bilingual individuals. Grosjean (1985) defined a bilingual speaker as "more than the sum of two monolinguals in the sense that the bilingual has also developed some unique language behaviour".

In general, bilingual individuals use different languages in different contexts/ situations for different purposes. Furthermore, individuals need not have to achieve a high level of competence of both languages to call themselves as bilinguals; rather a minimum level of knowledge of two languages is sufficient for them to communicate in different contexts (Grosjean, 1997). The concept of bilingualism was initially seen in border areas of different states of a country or between the two countries where the spoken languages are different. However, in recent times, several other factors contributed to increase in bilingual population across the world. These factors include migration, education system changes, globalization, trade and commerce, etc.

### 2.1.1. Scope of Bilingualism

From the international view, researchers from different parts of the world have reported that half of the world's population is bilingual. Although there are no studies which report the global statistics of bilingualism, it is very well known that bilingualism and multilingualism is seen in all age groups, all classes of culture and in most countries. Grosjean (1997) reported that over 50% of the world population is bilingual. De Bot (1992) reports that majority of the world's population is bilingual. European Commission (2006) reported that 56% of the population of 25 European countries speak a second language to communicate in different contexts. Grosjean (2013) reported that around 35% of the population in Canada and 18–20% of the population in United States are bilinguals. He also opined that the proportion of bilinguals is much higher in some parts of the world such as South Asian countries (eg., India) and African countries.

The scope of Bilingualism and multilingualism can be estimated based on the number of languages in the world and in each country. According to *SIL International's Ethnologue: Languages of the World* (1992), there are 6,909 spoken languages in 193 countries. Out of these 193 countries, some have very few languages whereas, some countries like India (445 languages), Indonesia (722 languages) have got large number of languages. This presence of large number of languages increases the percentage of language contact between the populations and increases the percentage of bilingual population. Apart from the language contact, the other major issues like business, education, employment, religion, politics, etc increases the percentage of bilingual population in many countries. Changes in education system are considered to be one of the major reasons for increasing in bilingualism and multilingualism in Indian context. The Indian education system follows three language rule in school education, where every child is forced to study and learn their native language (L1), national language (Hindi, L2) and English as third language. This forces all the children to learn three languages since their childhood and they become proficient in their 10 years of schools education. All these children are then considered as bilinguals and multilinguals with varied proficiency levels. These kind of social, cultural factors are leading to rising bilingual population across the world.

Coming to Indian bilingualism and multilingualism, it is very well accepted that India is one of the biggest bi/multilingual country in the world. Indian constitution has recognized 22 languages as official languages and there are around 1652 languages/ dialects which are spoken across the country. However, many of these languages and dialects do not have scripts. As per the 2001 census of India, approximately 25% of the total population are bilinguals in India which is high compared to that of 1991 census of India which reported only 19.44% of the total population is bilinguals in India. As per

2001 census of India, approximately 86 million Indians reported English as their second language and another 39 million Indians reported it as their third language.

### 2.1.2. Types of Bilingualism

Bilingualism is defined in many ways by different researchers across the world. These definitions were given based on different characteristics of bilingual population in terms of proficiency, age of acquisition, manner of acquisition, and so on. Thus, for each of the characteristics, bilingual population was divided into different types. Some of the major factors considered in classification or defining types of bilingualism include context of language acquisition, degree of proficiency, social status or attitude, manner of language acquisition, age of acquisition, and so on.

#### 2.1.2.1. Types of bilingualism on the basis of context of language acquisition

Weinreich (1953) gave the first classification and defined three types of bilingualism based on the context in which the two languages are acquired and also on how the two languages were encoded in a bilingual person. The three types are *coordinate bilingualism, compound bilingualism* and *sub-ordinate bilingualism.*

*Coordinate bilingualism*: In this type of bilingualism, the bilingual individual acquires the two languages in different environments/contexts; hence, the each word of the two languages is kept separate and has its own meaning in two languages, i.e., has separate lexicon for each of the language. This type of bilingual speaker functions as a native speaker in each language. An example for this type of bilingualism could be a child who acquires one language (native language) at home for few years and afterward learns a second language at school. According to Weinreich, in these children, a different lexical system would be formed and maintained for each of the learned languages. This type of bilingualism is commonly seen where the child learns a native language (Kannada or Telugu, etc.) up to the age of 3 years and later on, when the child goes to school, he starts learning English as a subject or medium of instruction.

*Compound Bilingualism*: in contrast to coordinate bilingualism, compound bilingualism is seen when one acquires both the languages in same context where they are used concurrently and therefore forming a single lexical system for both the languages. Compound bilingual would not function as native speaker of either of language since he uses the same lexicon for two languages.

*Sub-ordinate bilingualism*: this is a sub type of coordinate bilingualism, in which, the dominant language acts as filter for the other, thereby the person understands words in weak language through the words in their dominant language. An example could be interpreting of the English word ‘table’ activating the Kannada word ‘mEju’.

A simplified summary is given by Spolsky in 1998, who defined coordinate bilinguals as the ones who have two separate lexical systems for separate languages with its own set of words; whereas compound bilinguals are the ones who have single lexical system for both the languages.

Weinreich (1961) documented that other parts of the linguistic system, such as phonemes, tense markers, word order, etc are also susceptible to merging or coexistence in varied proportions. Hence, it is possible for someone to be coordinating at the level of syntax and semantics but to have compound phonology that is a broadened system, serving both the languages. However, Harding-Esch & Riley (2008) refer to this classification as not being an acceptable classification in the present time. This hypothesis has never been proven since most of the bilingual speakers fall somewhere in between the two types and it has been concluded that exclusive types of compound or coordinate bilinguals do not exist.

#### 2.1.2.2. Types of bilingualism on the basis of proficiency level

Proficiency level is one of the major factors in bilingualism research. The effect of proficiency levels is very high and it impacts the results of both neurolinguistic and psycholinguistic research of bilingualism. According to Macnamara's (1967a) definition of bilingualism, anyone with *minimum levels of competency* in two languages in any of the four skills, speaking, language comprehension, reading and writing are termed as bilinguals. However, this definition cannot be taken as working definition in research studies of bilingualism as the definition insists on minimum levels of competence in two languages, considering this poses a significant drawback in research, as the performance on both behavioral and objective tasks vary depending upon the proficiency levels. Based on the proficiency level in two languages, bilinguals can be divided as *balanced bilingual* or *dominant bilingual*. Similarly, they could also be referred as *high proficient* bilinguals or *low proficient* bilinguals.

*Balanced/ high proficient bilingualism*: Spolsky (1998) defined balanced bilingualism as "the condition, where the individual has a very strong command of both languages". A balanced bilingual is "someone who is more or less equally proficient in both languages, but will not necessarily pass for a native speaker in both languages" (http://www.bklein.de/buc/buc_classification.php retrieved on 26/02/2013).

*Dominant bilingualism*: is defined when an individual has much stronger command of one of the two languages. A dominant bilingual is a person who is more proficient in one of the two languages (http://www.bklein.de/buc/buc_classification.php retrieved on 26/02/2013).

In dominant bilingualism, the dominant language need not to be native language (L1) always. Again, this dominance may vary from task to task, i.e., a person may show dominance in listening comprehension but may not show dominance in speaking task. This dominance may vary according to context also, i.e., a person may show dominance in one language at one context (like dominance of L1 at home), whereas show dominance in other language in other context such as at work. This view is also expressed by Irujo (1998) who concluded that the language dominance varies from domain to domain and context to context. By considering these factors, one needs to examine proficiency levels across four language skills and across contexts in each language to draw information about proficiency of an individual.

#### 2.1.2.3. Types of bilingualism on the basis of age of acquisition

Age of acquisition was not considered as an important factor in bilingualism research until the advent of the concept of *critical period* which was proposed by Lenneberg in 1967. Lenneberg (1967) defined critical period as "it is 'automatic acquisition from mere exposure' that 'seems to disappear after this age', regardless of the exact nature of the underlying maturational causes". The *Critical Period Hypothesis* states that "the first few years of life constitute the time during which language develops readily and after which language acquisition is much more difficult and ultimately less successful (Siegler, 2006). It argues that due to maturational constraints, the ability to learn a language after puberty will disappear. It is now very well accepted that there is a critical period for first language acquisition, during which the child learns a particular language. If the child does not get exposed to language during this period, especially in the early years of life, they tend to lose ability to learn a language. Even if they acquire a language, they will be exhibiting subtle deficits in various components of language. However, there is a debate going on the issue of critical period in second language acquisition. Based on the age of acquisition, the bilinguals are divided as either *early bilinguals* or *late bilinguals*.

*Early bilinguals* are those who are exposed to both languages before adolescence and *late bilinguals* are those who acquired second language after adolescence. Few researchers propose that the early bilinguals are those who acquire both languages by the age of 13 years (Flege, Mackay, & Piske, 2002). Johnson and Newport, (1989) have concluded that there is a significant relation between age of acquisition and proficiency levels of various language tasks and these studies provide support to critical period concept. However, there are studies which oppose the concept of critical period and importance of age of acquisition of second language acquisition. One such study is by Birdsong and Molis (2001), who found that 17 out of 32 Spanish - English late bilinguals' performance was higher than 92% with one having performance within normal limits and 3 being at above 95% accuracy. These results indicate that there is no such age cut off for critical period before which the people have to learn second language. This study also supported the results of a study carried out by Long (1990) who rejected the hypothesis of critical period for second language acquisition.

#### 2.1.2.4. Types of bilingualism on the basis of manner of second language acquisition

This type of differentiation is based on the way in which the two languages are acquired. The two types of bilingualism in this category are *simultaneous bilingualism* and *sequential (successive or consecutive) bilingualism*.

*Simultaneous bilinguals* acquire the two languages together, similar to that of first language. The term 'similar' refers to factors like age of acquisition, exposure levels, and so on. Although, this type of bilinguals develops good language skills and stronger command over both the languages, the prevalence of this type of bilinguals is less but increasing (Chengappa and Ravikumar, 2008). In contrast, *sequential bilinguals* acquire first language initially and then learn second language at later ages. This type of bilinguals is most frequently seen. This is very high in the Indian context, where the child learns native language up to the age of 3 years and then learns second language at school from the age of 3 years.

### 2.2. Neurobiological basis of Language

The relation between language and neuroscience was emphasized by the observations of Paul Broca and Carl Wernicke on the localization of specialized expressive and receptive language areas in the brain. Broca and Wernicke have made important observations about brain – behavior relationship which was considered as the basis for modern neurolinguistic research across the world. The modern neurolinguistic research focused on identifying/ localizing cortical areas responsible for a range of language functions. These studies also focused on neuropathology associated with various speech and language disorders like aphasia, apraxia of speech, and so on.

#### 2.2.1. Central Nervous System: An overview

The adult human brain weighs up to 1500gms and it is formed by neurons and neuroglia cells. There are approximately 100 billion neurons in the nervous system, and each of these neurons may communicate directly with as many as 2,000 other neurons, providing at least 1 trillion points of communication. Every neuron receives information from other neurons and transmits to other neurons. Some of the neurons form a neuronal group which are organized as complex system and are responsible only for specific functions. The main portion of neuron is cell body which contains nucleus which consists of genetic material in the form of chromosomes. Other parts of neurons include dendrites, axon, myelin sheath, synaptic knob, synapse or synaptic gap. All the structures play important role in communicating the information from one neuron to the other in the form of electrical signals. These neurons are classified into three types on the basis of functional role namely, *sensory neurons* (passes sensory information), *motor neurons* (present in all the muscle cells throughout the body) and *inter-neurons* (provides connections between sensory and motor neurons). These nerve cells form nerve impulses which represent all the neuronal activity and with chemical property changes, it creates an electrical potential called as action potential. This action potential travels from nucleus to synaptic junction through axon, myelin sheath and dendrites and gets transmitted to other neuron through neurotransmitters.

The nervous system is divided into two systems, central nervous system (CNS) and peripheral nervous system (PNS). The central nervous system consists of brain and spinal cord. The peripheral nervous system consists of sensory and motor nerves that are connected to the spinal cord (spinal nerves) and the brainstem (cranial nerves). These nerves extend to the organs, muscles, joints, and so on, forming an elaborative network of connections throughout the body.

The cerebrum of the brain consists of two cerebral hemispheres. These cerebral hemispheres consist of gyri and sulci. These two hemispheres are separated along the midline by the longitudinal fissure. These hemispheres contain various small centers for processing various kinds of information received by the opposite side of the body. These hemispheres are specialized/ dominant for certain functions, for example, language and cognition are processed in left hemisphere and music and art related functions are dominant in right hemisphere. Each cerebral hemisphere consists of four primary lobes, *frontal, parietal, temporal* and *occipital lobes* which are separated by various sulci; and two secondary lobes, *insular and limbic lobes.* The insular lobe is a small cortical island in the depths of lateral sulcus, overlapped by frontal, parietal and temporal folds of cortex, whereas the limbic lobe includes medially located structures that are parts of the older brain (cf. Bhatnagar & Andy, 1995).

**Frontal lobe** is the largest and it occupies about one-third of the hemisphere in the anterior portion. This lobe consists of four major gyri. The precentral gyrus is the site of the primary motor cortex in which the entire human body is represented. It also consists of premotor cortex, responsible for complex and skilled movements; prefrontal cortex, responsible for major cognitive functions. The opercular and triangular portions of the inferior frontal gyrus in the dominant hemisphere constitute the anterior language cortex or Broca's area. Broca's area is important in spoken language and it is located in front of the area of the primary motor cortex. The **parietal lobe** is located between frontal and occipital lobes and above the temporal lobe. This lobe is mainly concerned with the perception of somatic sensation, elaboration of sensory experience, and integration of crossed modality information. It consists of primary sensory cortex, in which all modalities of somatic sensation are received. The entire parietal lobe is important in perceptual synthesis, spatial orientation, memory, and cognition. It also consists of two major areas, angular and supramarginal gyri in the inferior parietal lobule of the dominant hemisphere which are responsible for reading and writing skills.

**Temporal lobe** is located ventral to the frontal and parietal lobes. The lateral surface of the temporal lobe contains three prominent gyri: the superior, middle and inferior. This lobe has a major area called Heschl's gyri which is the primary auditory cortex. It receives projections from both ears. The auditory language associational cortex lies in the posterior superior portion of the first temporal gyrus, the area surrounding the primary auditory cortex. This association area in dominant hemisphere is concerned with the analysis and elaboration of speech sounds. **Occipital lobe** is the smallest of the four primary lobes and is located on the lateral surface in the posterior part of the brain. This lobe has the primary and secondary visual cortical areas responsible for visual processing.

The **brainstem** is a short extension of the brain that connects the diencephalon to the spinal cord and it consists of three structures: *midbrain, pons* and *medulla oblongata.* The brainstem is an integrator and coordinator of both central and peripheral acquired information and monitors all brain outputs. Brainstem is very important in automatic control of sleep and respiration. It contains sensorimotor nuclei which control facial movements and sensitivity. Nuclei of various cranial nerves are located in brainstem and hence it plays a role of relay station in transmitting the information to and fro from cerebral cortex to peripheral structures.

The **cerebellum** is located dorsal to the pons and medulla. It is separated from the cerebral hemispheres above by a meningeal layer of dura mater and from the brainstem by the fourth ventricle. This structure contributes to the maintenance of balance and coordination of motor activity by modifying cortical motor functions. With direct and indirect links to the motor cortex, basal ganglia, and spinal cord, the cerebellum coordinates and modifies the tone, speed, and range of muscular excursions in the execution of motor functions.

The **spinal cord** serves as the transmission link between the brain and the body. It transmits motor impulses from the brain to various visceral organs, muscles, and glands and it transmits sensory information from various body parts to the brain. The spinal cord begins as the caudal continuation of the medulla oblongata and it is approximately 42 - 45 cm long. The dorsal horns contain the sensory nerve cells that receive sensory information from body through dorsal root fibers. The ventral horns contain motor nerve cells that pass motor information between the brain and various organs.

The **subcortical structures** like basal ganglia and thalamus are the major structures which are important in speech and language processing. Basal ganglia are a group of cell bodies intimately related to the control of background movement and initiation of movement patterns. The ganglia include *caudate nucleus*, the *putamen*, and the *globus pallidus*. Lesions to basal ganglia result in extrapyramidal dysfunction, including hyperkinetic and hypokinetic dysarthrias. *Thalamus* is the largest structure of diencephalon and it is an important structure because of its relay function between cerebral cortex and peripheral structures. The nuclei of thalamus may be organized as *specific thalamic nuclei, association nuclei and subcortical nuclei.* Pulvinar nucleus is one of the major nuclei associated with language functions and damage to pulvinar nuclei can result in aphasia. Previous research done on language organization has focused mainly on the cortical areas and subcortical structures were considered to play role only in speech motor control. However, since past two to three decades, various studies challenged this traditional view and reported occurrence of language disorders following damage to subcortical structures. More insights into the role of subcortical structures were possible with the advances in the neuroimaging technologies which made CT, MRI, and fMRI techniques available for research on language functions. In general, there is an increase in number in aphasia cases following subcortical lesions involving *thalamus* and *striatocapsular region* (Murdoch, 2001). Modern neurolinguistic research also supports the role of various subcortical structures including thalamus and globus pallidus in language processing. The major research on the role of subcortical structures in language processing was carried out by studying the language deficits in individuals with subcortical lesions and the deficits were correlated with the results of neuroimaging.

### 2.2.2. Classical areas of Language

Bouillaud (1848) was the first researcher to argue that language was located in frontal lobes of the brain, in particular in the portion just above the eye socket. Later on in 1861, Paul Broca's presentation on localization of higher functions in the brain, Broca presented a case named 'Leborgne' who lost his speech at the age of 36 years and was hospitalized for 21 years. His comprehension of spoken language was reported to be normal and he could function independently during the course of hospitalization. Later on, he developed paralysis of right hand and right leg. Broca analyzed the brain immediately after the autopsy and found that there is a lesion in left frontal lobe, thus supporting Bouillaud's theory. After the detailed correlation of the symptoms linguistic and non-linguistic deficits in his case, he found only deficits in expressive language, what he termed as 'faculty of articulate language'. The major conclusion of this paper was that the expressive apparatus for speech is related to a small area of cortex just in front of the precentral gyrus, in the pars triangularis and opercularis of the third frontal convolution. Later on this area was named after Paul Broca as ***Broca's area*** (cf. Caplan, 1998).

In 1874, Carl Wernicke, a physician published a paper entitled "The symptom complex of aphasia: a psychological study on a neurological basis", in which he provided a classification of aphasic syndromes, and also a general model of how language is represented in the brain from which new syndromes could be predicted. He discovered that there were several subtypes of aphasic syndromes, each of which resulted from lesions in different areas of the brain. Along with the subtypes of aphasia, the other important finding of his research was identification of an area in the region of first temporal gyrus on the left hemisphere which is not a primary sensory nor a primary motor area, but it was an area which is thought to be memory store for the auditory form of words, and suggested that this region should be considered as a second center for language. This area is now known as ***Wernicke's area*** and it is located on the first temporal gyrus. These were the two major areas identified as important areas for language for years together. Wernicke termed the aphasia that resulted from lesion in Broca's area as *motor syndrome* and second type of aphasia caused by lesion in first temporal gyrus as *receptive deficit and an expressive disorder*. He also predicted that there could be third form of aphasia which can result from the lesions in connections (*arcuate fasciculus*) between Wernicke's and Broca's areas. This approach was later well exemplified by a paper by Lichtheim (1885) who proposed a complete enumeration of all aphasic syndromes based on connectionist model of language and the brain. These autopsy and brain – behavior studies discovered the major cortical structures involved in speech and language, i.e. *Broca's area, Wernicke's area and arcuate fasciculus*. These studies were considered as basis for all the modern neurolinguistic and psycholinguistic research studies aimed at studying the organization of cortical areas in processing of various types of language information.

Brodmann in 1909 identified and numbered areas of the brain based on cytoarchitectural organization of neurons, which is popularly known as **Brodmann areas.** Although this classification was considered as anatomical only, several studies were done to associate these areas with various functions. Hence, in modern neurolinguistic era, Brodmann areas were also considered as representation of functional organization of various areas. This led to identification of specific areas responsible for speech, language and cognitive functions. Major areas in *speech and language* are area 44 (Broca's area), area 9, 10, 11 (associated with cognitive functions), area 4 (primary motor area), area 39, 40 (angular and supramarginal gyrus), area 22 (Wernicke's area).

## 2.3. Aphasia

A number of definitions of aphasia are present in the literature and differ in their technical competence. Benson (1979) defined aphasia in simplest way as "the loss or impairment of language caused by brain damage". This definition was considered as suitable one by many researchers as it includes the necessary elements like loss of language and brain damage. However, other researchers challenge this definition on the factors like aphasia is not the only language disorder that is caused by brain damage, but there are several other disorders like dementia, closed head injury, right hemisphere damage, and so on. Therefore, these researchers emphasized on having a more specific definition of aphasia. Darley (1982) had proposed another definition of aphasia as "impairment, as a result of brain damage, of the capacity for interpretation and formulation of language symbols; multimodality loss or reduction in efficiency of the ability to decode and encode conventional meaningful linguistic elements (morphemes and larger syntactic units); disproportionate to impairment of other intellective functions; not attributable to dementia, confusion, sensory loss, or motor dysfunction; and manifested in reduced auditory retention span and impaired efficiency in input and output channel selection". Later on, Goodglass and Kaplan (1983) defined aphasia as "disturbance of any or all of the skill, associations and habits of spoken or written language, produced by injury to certain brain areas that are specialized for these functions".

Cerebrovascular accident or stroke is one of the major causes of aphasia. Other causes include traumatic brain injury (MacDonald, Code, & Togher, 2000), degenerative disorders, tumors, dementia (Au, Albert, & Obler, 1988), and so on. Sethi (2002) have estimated the prevalence of stroke in India as 203 per 100,000 population, amounting to a total of about 1 million cases. Sudlow and Warlow (1997) have reported that incidence of stroke is lower in France (238 per 100,000), and higher in Russia (627 per 100,000). Brust, Shafer, Richer, and Brown (1976) estimated that approximately 20 percent of those who have had an acute stroke will have aphasia. Klein (1995) suggested that the incidence is about 83,000 in the Unites States of America and a prevalence of one million people with some degree of aphasia.

The signs and symptoms vary depending upon the site of lesion and extension of lesion in individuals with aphasia. The classification model also called as Wernicke-Lichtheim-Geschwind model given by Geshwind, 1965 was taken as the basis for development of several test batteries which in turn classifies aphasic individuals into different types of aphasia. The early classification of aphasia is *fluent* and *non-fluent* types of aphasia. Aphasia is non-fluent if speech is hesitant and slow with many pauses and a lack of articulatory precision and prosody in speech. Apraxia of speech may also be present in some of the aphasic individuals as an associated symptom. These individuals will also have deficits in spontaneous speech, repetition, and naming aspects. However, their auditory comprehension skills are preserved, hence, they could comprehend spoken language. In fluent type of aphasia, individual will have a very fluent speech without any hesitations, pauses but have more difficulties in auditory comprehension. The ***fluent type*** of aphasia includes Wernicke's aphasia, conduction aphasia, transcortical sensory aphasia, anomic aphasia. The ***non-fluent type*** of aphasia includes global aphasia, Broca's aphasia, transcortical motor aphasia, mixed non-fluent aphasia.

**Wernicke's aphasia** is one of the fluent types of aphasia with very fluent speech, with no grammatical disturbances but with semantic (verbal & literal) paraphasias. The site of lesion is located in Wernicke's area, Brodmann's areas 21 and 42. Often, the damage extends into parietal lobe affecting angular gyrus, brodmanns's area 39 resulting in associated reading and writing disorders. The major impairment is in terms of auditory verbal comprehension. Articulation and prosody are unaffected and their speech is paragrammatical but not agrammatical in nature. In most severe cases, speech may be essentially meaningless and sounds like 'Jabberwocky' type of speech. Repetition is affected and frequent word finding problems are seen. Along with the regular language deficits, Wernicke's aphasics tend to have anosognosia or denial of their communication problems.

**Anomic aphasia** is characterized by a pervasive impairment of word finding, which contrasts with intact repetition, fluent and grammatically correct speech and good auditory comprehension. It is very vital to differentiate classic anomic aphasia from anomia or naming disorders present in other aphasias. Although specific lesion could not be identified for anomic aphasia, the lesion is often in temporo-parietal area including angular gyrus. Naming or word finding difficulties are the major feature of this type of aphasia. Auditory comprehension is relatively preserved and repetition is good. Speech is more fluent and grammatical in nature. Reading and writing difficulties vary from mild to severe levels.

**Conduction aphasia** is majorly caused due to lesion in arcuate fasciculus, an association type of nerve fibres connecting Broca's and Wernicke's areas. However, both Broca's and Wernicke's areas are intact in this condition. This type is mainly characterized by poor repetition skills compared to fluency and auditory comprehension. Spontaneous speech is fluent and literal paraphasias are present in speech. Reading and writing skills are reported to be good. Though they can repeat short sentences, they will have more difficulty in repeating syntactically complex sentences.

Individuals with **transcortical sensory aphasia** have fluent and paraphasic speech with intact repetition but have severe impairment only in auditory comprehension. The intact repetition skills are the major difference between Wernicke's aphasias and transcortical sensory aphasias. Site of lesions would be found in Brodmann's areas: 37, 22, and 39. Well preserved repetition skills indicate that the arcuate fasciculus, Wernicke's area and Broca's areas are intact but are cut off from the rest of the brain due to infracted tissue.

**Global aphasics** are present with an almost complete loss of ability in all the domains including spontaneous speech, auditory comprehension, repetition, and naming. Lesions can be found in both anterior and posterior portions of the brain in this type of aphasia. Propositional speech may be reduced to a few words. Hemiplegia or hemiparesis accompanies in most of the patients.

**Broca's aphasia** is the most frequently seen non-fluent aphasia. The other names include expressive aphasia, motor aphasia and efferent motor aphasia. This type of aphasia is majorly caused due to lesions in Broca's area, Brodmann's areas 44 and 45. The speech is non-fluent with few rods and short sentences, often non-meaningful and many intervening pauses. Repetition and naming are impaired to the core with near normal to normal auditory comprehension skills. Verbal output is more like telegraphic speech, only nouns, verbs and adjectives and adverbs are retained. Apraxia of speech is associated in many individuals with this type of aphasia. Sentence length is short and syntactic structures are severely affected making the speech agrammatical. Articulatory precision and prosody are affected with few literal paraphasias. Hemiparesis of the right side is most commonly seen.

Individuals with **transcortical motor aphasia** have intact repetition but speech is nonfluent with more phonemic paraphasias, perseverations. The lesion is usually in the connections between Broca's area and pre-motor or supplementary motor areas. Studies also show lesions in subcortical structures (basal ganglia and thalamus) and connections between subcortical and cortical areas. These individuals have normal repetition skills. However, the patient will have great difficulty initiating conversations. Articulation and confrontation naming abilities are preserved and auditory comprehension is near normal to normal levels.

**Mixed non-fluent aphasia** is seen very rarely, in which, the fluency is affected to the maximum and speech is more similar to telegraphic speech with impaired auditory comprehension deficits that are severe than Broca's aphasics.

Several tests and batteries are available for assessment of language deficits in individuals with aphasia. Some of them focus on classifying type of aphasia, some on measuring the severity of aphasia and some on assessing specific language skills in individuals with aphasia. These tests are again classified based on the screening, diagnostic and functional communication assessment tests. Boston Diagnostic Aphasia Examination (BDAE, Goodglass & Kaplan, 1972) and Western Aphasia Battery (Kertesz, 1982) are the two major diagnostic test batteries developed to classify the type of aphasia into various types. Other than these two tests, there are other tests to assess individual language functions include Porch Index of Communicative ability (Porch, 1967), Minnesota Test for Differential Diagnosis of Aphasia (MTDDA, Schuell, 1965) and Boston Naming Test (Kaplan, Goodglass & Weintraub, 1983). Screening tests include Aphasia screening test (Reitan & Wolfson, 1985), Bedside evaluation screening test – 2$^{nd}$ edn (West, Sands, & Ross-Swain, 1998), Frenchay Aphasia Screening Test (Enderby, Wood, Wade, & Langton Hewer, 1987).

**Rehabilitation** of aphasics involves a multidisciplinary team approach which consists of neurosurgeon, neurophysician, speech language pathologist, physiotherapist, psychologist, and family members. The treatment is mainly divided into pharmacotherapy, speech language therapy and cognitive therapy. Under speech language therapy, many researchers across the world have developed some specific therapy techniques like Melodic Intonation Therapy (MIT, Sparks, Helm, & Albert, 1974), Visual Communication Therapy (Gardner, Zurif, Berry, & Baker, 1976), Visual Action Therapy (Helm & Benson, 1978), Functional Communication Therapy (Aten, Caligiuri & Holland, 1982), Promoting Aphasics Communicative Effectiveness (Davis & Wilcox, 1985), and so on.

### 2.4. Neuropathology of aphasia

The neuropathology of aphasia varies with the underlying cause and extent of lesion. The major causes of aphasia are cerebrovascular accident or stroke, traumatic brain injury, tumors, neurodegenerative disease, and so on with stroke being the major cause of aphasia. The general incidence and mortality rates of stroke are high and it is estimated that 500,000 to 700,000 new cases occur every year. In spite of early identification of risk factors and treatment of risk factors, it remains as the third major cause of death in Western countries which is more or less similar in Indian context also. Stroke occurs in individuals over 55 years of age; however, there is an increased incidence of stroke in younger population in recent times due to change in life styles and other factors.

**Stroke** causes sudden loss of neurological functions by disrupting the blood supply to the brain, culminating within minutes or hours. This occurs when there is a sudden alteration of blood flow in any of the arterial territory (anterior, middle or posterior). This can be caused due to insufficient blood to the brain leading to death of neural cells due to lack of oxygen (ischemic stroke) or excess blood pressure leading to bleed internally into the brain parenchyma or into the subarachnoid space (hemorrhagic stroke).

***Ischemic stroke*** occurs due to lack of arterial blood flow in any of the specific cerebral arteries to maintain the functional neuronal activity. This can be due to intrinsic vascular occlusion (thrombus) that occurs in the neck portion of the internal carotid artery, vertebral artery, or a cerebral artery; or vascular occlusion with material originating elsewhere (embolism) such as a stenotic site of the internal carotid artery or vertebral artery or from the heart. Ischemic stroke occurs due to inadequate cerebral blood flow to a brain area causing total lack of oxygen and glucose to neurons which leads to suppression in electrical activity and causes loss of consciousness. When the blood flow falls below 8mL/100 g of brain per minute as against the normal value of 50mL/100 g of brain, neuronal death starts occurring as early as 15 minutes after flow disruption. The signs and symptoms vary depending upon the site of the occlusion. Occasionally, there are chances for leakage of blood through damaged small arterioles, capillaries and venules, due to rapid reperfusion of the ischemic territory from lyses of the embolic clot causing hemorrhagic transformation of ischemic stroke. *Transient ischemic attacks (TIA)* are disturbances of the blood supply to a specific area of the brain for short duration between 2 – 15 minutes, which produces temporary, focal lesion. *Reversible ischemic neurological defects (RIND)* refer to the attacks that continue for more than 12 hours without interruption (cf. Davis, King, & Schultz, 2005).

***Hemorrhagic stroke*** refers to bleeding into the brain parenchyma that may extend into the ventricles and rarely into the subarachnoid space. Intracerebral haemorrhages most commonly occur in the cerebral lobes, basal ganglia, thalamus, pons, and cerebellum. The bleeding results from the rupture of small penetrating arteries originating from the basilar artery or anterior, posterior or middle cerebral arteries. The blood flows into surrounding areas rapidly and compresses brain which in turn develops vasogenic edema from release and accumulation of osmotically active clot proteins and cytotoxic edema from compression of surrounding blood vessels, producing secondary tissue ischemia. *Subarachnoid hemorrhage* is the presence of blood in the meninges and cerebrospinal fluid (CSF). This is caused due to rupture of a saccular or fusiform aneurysm. Major risk factors for rupture of an aneurysm include hypertension, smoking, heavy alcohol consumption, and a positive family history.

**Traumatic brain injury (TBI)** is the most frequent cause of death and disability in young adults all over the world. This is also a major cause for aphasia after stroke in both Indian and Western context. In young adults, road traffic accidents are the leading cause while in older adults, falls prevail. Brain damage from TBI is divided into two mechanisms: primary and secondary brain injury (cf. Davis, et al, 2005). Primary injury occurs at the moment of head trauma, with several factors contributing to the brain damage. Secondary injury is a multifactorial process that initiates at the moment of injury but does not present clinically until later. Brain swelling, the most important cause of secondary injury, begins shortly after the TBI. TBI is graded as mild, moderate, and severe levels based on the Glasgow coma scale (GCS). The scale is based on responses to eye opening, limb movements, and verbalization. Apart from CVA or stroke and traumatic brain injury, aphasia may also be caused due to some of the neurodegenerative disorders, tumors, etc.

## 2.5. Language deficits in Aphasia

### 2.5.1. Phonological deficits in individuals with aphasia

Phonological and phonetic deficits are commonly seen in individuals with aphasia along with other disorders such as lexical and syntactic deficits. The deficits may be at the level of linguistic level (phonological) or at the articulatory (phonetic) system or auditory in speech perception. Blumstein (1990) reported that sound structure of language is shaped not only by physiological constraints of the speech system in speech production and the auditory system, but also by constraints and principles that are unique to language itself.

Each language has its own system of sounds and specific rules of how these sounds can be combined to form meaningful utterances. The sound segments are represented at two levels: phonological and phonetic. The phonological level is a part of the central language system where each phoneme has a got a meaning. This phonological level also processes the stress and intonation patterns of each language. Each phoneme gets identity at physical level through articulatory and acoustic characteristics at phonetic level.

The research on deficits in speech production of individuals with aphasia has been done on both aspects, phonological and phonetic level. The research studies show that phonological errors are seen in almost all individuals with aphasia. Blumstein (1998) classified these phonological errors into four major types: *phoneme substitution errors, simplification errors, addition errors* and *environment errors.* The type of phonological errors varies in different types of aphasia. Usually, the phoneme substitution errors in individuals with aphasia are limited to replacement of one of phonetic features, voicing or place of articulation or manner of articulation. Blumstein (1990) reported that the simplification and addition errors are simplest in nature, where either consonants get deleted or added in the beginning of word. Environment errors like influencing other phonemes occur across word boundaries preserve the syllable structure relations of the lexical items.

The initial research on phonological deficits in individuals with aphasia was carried out in English language (Milberg & Blumstein, 1981; Caramazza, Papagno, & Ruml, 2000; Kohn & Smith, 1990). These phonological deficits were also evident in several other languages: German (Bouman & Grunbaum, 1925; Goldstein, 1948), Mandarian (Naesear & Chan, 1980), Turkish (Peuser & Fittschen, 1977), French (Lecours & Lhermitte, 1969) and Russian (Luria, 1966). However, the errors seen in individuals with aphasia are inconsistent, i.e., the person may produce a phoneme incorrectly sometimes but may produce the same word correctly in certain times. Blumstein, (1973), and Hatfield and Walton, (1975) reported that the errors are bidirectional, meaning the voiced consonants may be produced as voiceless and voiceless sounds may be produced as voiced sounds. These results indicate that the individuals have the ability to produce the specific phoneme or specific acoustic features. The reported phonemic or phonetic errors are thought to be due to poor phonological encoding of the correct phonemic representation of the word. Butterworth (1992) concluded that individuals with aphasia have deficits only in accessing these representations but their phonological representations are intact. These deficits are termed as selection or phonological planning deficits.

Several research studies report that anterior aphasics have more difficulty in producing phonetic aspects that involve timing of two autonomous articulators like in nasal and voicing phonetic dimensions (Blumstein, Cooper, Goodglass, Statlender, & Gottlieb, 1980; Freeman, Sands, & Harris, 1978; Shewan, Leeper, & Booth, 1984). However, this particular pattern may vary from language to language depending upon the variations in the phonetic system of the language. Studies on articulatory timing using x-ray microbeams (Itoh, et al., 1980) and EMG (Shankweiler, Harris, & Taylor, 1968) have also reported that timing relations between the articulators is affected. Baum, Blumstein, Naeser, and Paumbo, 1990, and Tuller, 1984 reported that the anterior aphasics have deficit affecting specific articulatory manoeuvres, such as timing or integration of movements of articulators, rather deficits in articulatory production of the various acoustic features. The similar types of results were also seen in the acoustic analysis of vowels, in features of formant frequencies.

Individuals with aphasia also show deficits in auditory perception of different speech sounds and words which involves encoding of auditory input, forming of phonological representations for the input signals, and associating the specific word to the matching lexical item in the system. Individuals with aphasia may have deficits at any or all the levels which affects their auditory/ speech perception. These impairments can be in terms of perceiving the phonological patterns of language, perceiving the acoustic properties that correspond to the phonetic characteristics of speech, and impairments in associating sound structure to lexical form. Studies on individuals with aphasia have reported significant deficits in processing segmental contrasts in both words and nonwords. Although the severity of auditory comprehension deficits are high in Wernicke's aphasia according to classical view (Luria, 1966), results of various studies show that most of the individuals with aphasia have deficits or difficulty in phonological discrimination (Blumstein, Baker, & Goodglass, 1977; Miceli, Gainotti, Caltagirone, & Massulo, 1980). Goswami (2004) have reported that the individuals with aphasia performed poorly when compared to typical individuals on phonological tasks in Kannada language. Within aphasia group, individuals with nominal aphasia, transcortical sensory, transcortical motor aphasia and conduction aphasia have performed better than individuals with Broca's, Wernicke's and global types of aphasia on phonology comprehension deficits. Santosh & Goswami (2012) have also reported significant differences in the performance of typical individuals and individuals with Broca's, global, Wernicke's and anomic types of aphasia on syllable identification and syllable discrimination in auditory modality. These deficits in speech perception are not limited only to phonological level, but also to phonetic characteristics of speech sounds. Individuals with aphasia have significant difficulties in perceiving several differences in phonetic or acoustic features of speech sounds. Several research studies show that the individuals with aphasia have difficulty in perceiving voicing features (Basso, et al., 1977; Gandour & Dardarananda, 1982). However, the suprasegmental features of speech, such as intonation and stress in both tonal (Thai and Chinese) and non-tonal languages are affected mildly in individuals with aphasia (Baum, Kelsch, Daniloff, & Daniloff, 1982; Blumstein & Goodglass, 1972; Green & Boller, 1974; Gandour & Dardarananda, 1983; Naeser & Chan, 1980).

### 2.5.2. Morphological and Syntactic deficits in individuals with aphasia

Among the five components of language, *morphology* deals with rules of word formation, organization of words into functional and content words (word level); and *syntax* deals with construction or formation of sentence. Words in most of the languages including English can be divided into several major categories and the major classification being 'content' and 'function' words. Content words include nouns, adjectives, verbs, and some adverbs and prepositions. Function words, majorly affixes or morphological items are vocabulary elements which are appended to words during the process of word formation. Even though the words are the basic elements of any language, the conversation or communication is not done at single word level, rather done at phrase or sentence level. Each language has its own rules for formation of sentences which include processing of word order, word classes, and phrase construction. At neuroanatomical and physiological level, Broca's area and its surrounding areas are identified as responsible for syntactic processing (Grodzinsky, 2000).

Deficits in syntax and morphology are considered as major deficits in individuals with non-fluent aphasia. Research studies on individuals with aphasia have provided sufficient information to understand the nature of these deficits in detail at both comprehension and production level. Majority of research studies have focused on identifying expressive deficits in syntax (Goodglass, Christiansen, & Gallagher, 1993; Grodzinsky, 1990; Zurif, 1995). However, other studies by Caramazza & Zurif, 1976; Heilman & Scholes, 1976; Damasio & Damasio, 1992; Goodlgass & Kaplan, 1983, have explored syntactic deficits at receptive level in individuals with aphasia. Although the traditional classification of aphasia classifies aphasic syndromes into non-fluent and fluent types based on expressive and receptive deficits respectively, non-fluent aphasics do exhibit some kind of comprehension deficits at sentence level and fluent aphasics do exhibit expressive deficits at sentence level.

In non-fluent aphasics, specifically in individuals with Broca's aphasia, *agrammatism* is frequently seen syntactic deficit at expressive level. Although there is no straightforward definition, agrammatism is explained in many ways in terms of its characteristics. Miceli et al., (1983) and Saffran et al., (1980) reported of problems in production of function words, but verbal inflection intact, although the verbal form might be semantically inappropriate in agrammatism. Caramazza and Hillis (1989) reported of problems with processing function words only when produced within a sentence but not at word level in isolation. Generally it is defined as "a lack of use of grammar in production and/or comprehension". Expression is typically characterised by a feature called 'telegraphic speech' which is defined as lack of function words and inflections. The main features of spontaneous speech of agrammatic patients include lack of function words, difficulty in production of verbs and telegraphic speech (Micceli, Silveri, Villa, & Caramazza, 1984; Saffran, Berndt, & Schwartz, 1989; Thompson, Shapiro, Li, & Schendel, 1994; Zingeser & Berndt, 1990).

Individuals with Broca's aphasia differ in their performance from one language to another on grammatical deficits as shown in cross-linguistic studies in different languages with varied sentence construction rules (Bates, Friederici, Wulfeck, & Juarez, 1988; Slobin, 1991). These cross-linguistic differences are also reported in various grammatical aspects such as omission of grammatical inflections, function words in one language (Bates, Friederici, & Wulfeck, 1987b), omission of tonal aspects in Chinese (Tzeng, Hung, & Bates, 1996).

In Indian context, Chengappa and Bhat (2000) reported of syntactic deficits in both production and comprehension levels Kannada speaking individuals with Broca's aphasia. Errors reported were seen on morphophonemic structures, tenses, person-number-gender (PNG) markers, case markers, comparatives, conditional and participle clauses during comprehension. In spontaneous speech, subjects showed abundance of nouns in their utterances with reduction of other syntactic structures. Aithal, Veena, James, Rajashekar (2009) studied morphosyntactic deficits in comprehension and expression in Malayalam speaking individuals with Broca's aphasia. On comprehension tasks, individuals with aphasia have performed poorly on tenses, participle construction, comparatives. On expression task, subjects performed poorly on participle constructions, comparatives, conjunctions, plurals, and tenses, and performed better on negatives and transitives. These results are similar to the studies done in western context by Slobin, 1991; Nadeu & Rothi, 1992; Kim & Thompson, 2000; Tesak & Hummer, 1994).

The syntactic deficits are also seen in individuals with fluent aphasia upto some extent, especially in individuals with Wernicke's aphasia, which are called as paragrammatism. In paragrammatism, unlike agrammatism, patient speaks at a normal rate with natural speech prosody. However, their major deficits include reduced variety and complexity of sentence structures with minimal deficits in other grammatical aspects such as omissions, substitutions of grammatical structures. However, there are several studies which provide evidence that both agrammatism and paragrammatism are similar in nature with only difference being in their adaptive control (Grodzinsky, 1984; Kolk et al., 1985).

The syntactic deficits are also reported in comprehension of syntactic information in individuals with aphasia. Various studies have explored the comprehension deficits in aphasics and also reported of a correlation between comprehension deficits and expressive deficits (Caplan & Hildebrandt, 1988; Martin & Blossom-Stach, 1986). However, there are also studies which contradict these results and report that there is no relation between expressive and receptive deficits (Kolk & Van Grunsven, 1985). Short-term memory deficits were reported as source of syntactic comprehension deficits in individuals with conduction aphasia by various authors (Caramazza et al., 1981; Saffran & Marin, 1975). Several studies were done to explore the underlying neurofunctional mechanisms using objective methods such as fMRI, ERP studies which will be discussed in the subsequent sections.

### 2.5.3. Lexical/ Semantic deficits in individuals with aphasia

Lexical/semantic deficits refer to deficits in lexical processing at single word level due to deficit to any of the lexical component (Rapp & Caramazza, 1998). Lexical deficits are frequently seen in individuals with brain damage especially in individuals with aphasia. Several models were developed and proposed to explain the lexical system in past. Theory of functional architecture of the lexical system (Morton, 1981) is a widely accepted theory which is developed to explain the lexical processing. This theory has explained lexical processing in two stages, input (comprehension) and output (expression) components. These components have two modalities of orthographic and phonological variety to explain the processing of written and verbal information. Both input and output components are mediated through lexical semantic system which is the repository of the meaning of words or concepts (Jackendoff, 1983; Miller & Johnson-Laird, 1976). According to this theory, lexical deficits in individuals with aphasia are caused due to deficiency in any one of the components. However, these internal components are influenced by other factors such as frequency, abstractness, word class, and so on.

According to the cognitive models of semantic processing, lexical processing takes place at two stages, one at lexical representation (lemma level) and the other at developing phonological forms for the words. These models explain different types of paraphasias and other naming deficits in individuals with aphasia depending upon the deficit at each level. Any failure at lexical representation or lemma level results in semantic paraphasias (eg., /camel/ for /horse/) and failure at forming phonological description results in phonemic paraphasias (eg., /cook/ for /book/). Individuals with aphasia following CVA or brain damage will have language impairments which are caused due to impaired lexical system. These impairments in semantic system or lexical system lead to disordered retrieval of words at production and also at comprehension or recognizing words (Howard & Orchard-Lisle, 1984). Impairments of word retrieval or lexical-semantic processing are seen in all the traditional types of aphasia in the form of anomia or naming deficits and also in individuals with Alzheimer's disease.

Individuals with anomic aphasia have intact semantic memory and are activated normally compared to other types of aphasia (Chenery, Ingram, & Murdoch, 1990). At sentence comprehension level, individuals with anomic aphasia have difficulty only with certain types or class of words (eg., inflections) (Smith & Bates, 1987). More deficits in naming nouns are reported than on naming verbs in individuals with anomic aphasia (Miceli, et al., 1984; Williams & Canter, 1987). Individuals with optic aphasia have difficulty in naming pictures or objects due to deficits in specific semantic systems for visual and verbal semantics (Beauvois & Saillant, 1985; Ferreira, Guisiano, Ceccaldi, & Poncet, 1997). Neologisms, pure word deafness, and jargon speech are the major characteristics of speech of individuals with Wernicke's aphasia (Kirshner, Webb & Duncan, 1981; Micelli, et al., 1980).

Individuals with non-fluent aphasia also have word retrieval deficits and naming deficits. Word retrieval deficits are more in Broca's and Global aphasias with more deficits in picture naming and generative naming (Sloan, Mitchum, Haendiges, &

Sandson, 1997; Williams & Canter, 1982). However, the severity of deficits varies depending upon the semantic features of the target words such as frequency of words, imageability, concreteness of the words, and so on (Warrington & Cipolotti, 1996; Zingeser & Berndt, 1990). At comprehension level, individuals with aphasia do exhibit difficulty in comprehension of some categories of words than others or comprehension is even limited to specific semantic categories (Crutch & Warrington, 2003; Forde & Humphreys, 2002; Kertesz, Davidson, & McCabe, 1998; Warrington & Shallice, 1984).

### 2.6. Neurolinguistics of Bilingualism

The field of neurolinguistics is majorly concerned with studying how language is organized and processed in brain. Studying how two or more languages are represented in bi and multilinguals has been the central focus of various neurolinguistic research studies in the past two to three decades with use of latest imaging technology in studying clinical population. The neurolinguistic research on neural organization of multiple languages has been conducted in two methods, one, studying individuals with bilingual aphasia and second is by the use of advanced imaging technology and electrophysiology techniques (Fabbro, 1999). Both the methods have proven to be valid and provided much needed information on processing of multiple languages in human brain although there are some contradictions between the studies.

#### 2.6.1. Clinical research in Neurolinguistics

Research studies on bilingual aphasia are again divided into two sections, one being associating each language deficits in each language to area of brain damage to understand the neural organization of each component of language and the second being the recovery patterns in each language in individuals with bilingual aphasia (Fabbro, 1999; Ijalba, Obler, & Chengappa, 2012). The study of aphasia to understand various aspects of neural organization has begun with study of Paul Broca (1865) who identified an area, inferior part of the third frontal convolution in left frontal lobe as an area responsible for motor acts of spoken words. Several other studies by Carl Wernicke (1874) and other researchers have explored the association between brain structures and language functions with identification of areas responsible for comprehension of language in left temporal gyrus (Wernicke, 1874) and connections between these two areas (arcuate fasciculus) as responsible for repetition of spoken words or sentences. These inventions of various language areas in brain have led to formation of connectionist models of language processing which classified different types of aphasias. In late 19th century, these initial observations have formed a basis for understanding neural organization in bi and multilinguals by studying brain damaged population and also by using imaging technology.

The major advancement in neurolinguistics of bilingualism has taken place with identification of five recovery patterns in bilingual individuals with aphasia by Paradis in 1977. They are (1) parallel recovery, (2) differential recovery, (3) selective recovery, (4) successive recovery, and (5) antagonistic recovery. These patterns have not only provided information about recovery processes but also provided information on overlapping and distinct neural representations of various languages in the brain. Albert & Obler, 1978, and Fabbro, 1999 have reported parallel recovery patterns in both languages indicating involvement of same areas in processing both L1 and L2. However, there are several other researchers who reported of selective or differential recovery of one language over the other in individuals with bilingual aphasia indicating involvement of distinct areas in processing of L1 and L2 (Gomez-Tortosa, Martin, Gaviria, Charbel, & Ausman, 1995; Nilipour & Ashayeri, 1989). The differential impairments also do provide enough information about similarities or dissimilarities in neural organization of multiple languages (Charlton, 1964; Fabbro, 1999; Obler & Albert, 1977). However, there are several other factors which may have an influence on these differential impairments or differential/selective recovery patterns such as order of acquisition (Ribot, 1881), the language most used at the time of brain damage (Pitres, 1895), the language that is more used during recovery process (Bay, 1964). Ribot's rule (Ribot, 1881) assumes that the language that was learned first will be the first to recover and will be less impaired than other languages. Pitres' (1895) rule proposed that premorbid familiarity in each language was more useful in predicting the recovery patterns in individuals with bilingual aphasia. Although, these hypotheses and studies provide valid information, the actual recovery patterns do not always provide information about specific areas involved in processing of each language.

Studies on crossed aphasia did throw some light on importance of right hemisphere in language processing in bilinguals and formed as basis for laterality research on typical individuals (Albert & Obler, 1978; Alexander & Annet, 1996; Gloning & Gloning, 1965; Karanth & Rangamani, 1988). In laterality research, researchers have used methods of dichotic listening, tachistoscopic methods to study language lateralization in bilinguals. The results of laterality research have confirmed overlapping areas for both L1 and L2 in left hemisphere and they also provided information on involvement of right hemisphere.

The research on neurolinguistics of bilingualism has been on clinical population by using behavioural methods until 1970s. However, with development of cortical stimulation technique in 1970s, the neurolinguistic research has moved to an advanced level in which the brain activity during language was observed closely. The major studies of cortical stimulation were carried out to map the language areas in epileptic patients (Penfield & Roberts, 1958) and on bilingual patients (Ojemann & Whitaker, 1978).

Results of these studies revealed involvement of some common and some distinct areas in brain for naming in different languages (Ojemann & Whitaker, 1978).

### 2.6.2. Imaging technology in Neurolinguistic research

The research on neurolinguistics of bilingualism is enhanced by innovation of noninvasive imaging technology including functional imaging techniques such as Positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). These techniques have enabled researchers in the field of neurolinguistics to validate the findings of studies on clinical population and also helped in developing new functional theories about language organization in bilingual individuals.

Klein, Zatorre, Milner, Meyer, and Evans (1994) in their study using PET reported that similar patterns of activation when the English-French bilinguals produced words in English and French. Klein, Milner, Zatorre, Meyer, and Evans (1995) have also reported similar results on tasks of repetition, translation, rhyme- and synonym generation in both languages in bilinguals. However, a study by Perani, Dehaene, Grassi, Cohen, Cappa, Dupoux, Fazio, and Mehler (1996) have reported that distinct areas are activated during comprehension of stories in Italian-English bilingual adults who acquired second language after the age of seven years. These studies have concluded that several other factors like age of acquisition, inter-subject variability have an effect on results of PET studies.

Perani et al., 1998 have carried out studies by considering age of acquisition and proficiency levels as factors using PET technique. Results revealed activation of similar areas for both groups of bilinguals in both languages. The authors have concluded that proficiency level in each language play a major role than that of age of acquisition in neural representation of different languages in bilinguals. Similar results were also reported by Tierney, Varga, Hosey, Grafman, and Braun (2001), Petersen, van Mier, Fiez, and Raichle, 1998; Price, Green, and von Studnitz (1999), Rinne, Tommola, Laine, Krause, Schmidt, Kaasinen, Teras, Sipila, and Sunnari (2000). Among these studies, Klein et al., 1994, 1995; Perani et al., 1998; Tierney et al., 2001, have reported that both languages have shown similar activation of brain. Whereas, other studies by Perani et al., 1996; Price et al., 1999; Rinne et al., 2000 have reported distinct activation patterns for each language in bilinguals. These differences in results have been attributed to the factors of intersubject variability, proficiency level, age of acquisition and other factors.

Functional magnetic resonance imaging (fMRI) technique has made it possible to localize functional brain activation with high spatial resolution and with better temporal resolution than that of PET technique. Initial studies using fMRI have validated the theories and models of language organization and processing. These techniques have also revealed involvement of several other areas in middle and inferior temporal gyri and temporal pole, in middle prefrontal areas and the insula during language processing. However, results of behavioural studies have shown that these areas are specialized for specific components of language processing (Alexander, Hiltbrunner, & Fischer, 1989; Hillis & Caramazza, 1991; Damasiao, et al., 1996).

## 2.7. Bilingual Aphasia: language deficits, assessment and treatment of bilingual aphasia

### 2.7.1. Bilingual Aphasia

Bilingualism and language organization is a complex phenomenon and studies are still ongoing to understand language organization in bilinguals at brain level in typical and clinical population. The increase in bilingual and multilingual population across the globe and change in life style is leading to increased brain damaged bilingual speakers due to CVA. Some individuals may show similar type of aphasia in both L1 and L2 on regular test batteries, on the other hand, there are group of individuals who demonstrate different types of aphasia in L1 and L2. The variations in symptoms between languages have been attributed to several factors like age of acquisition of each language, proficiency level, usage levels, structural differences between L1 and L2, and so on. The study of bilingual aphasia provides information about the language processing and organization in bilinguals, differential effect of brain damage on different languages.

The initial studies on bilingual aphasia have focused majorly on recovery patterns in these individuals. The recovery patterns in bilingual individuals with aphasia vary in relation to the relative impairments in two languages (Paradis, 1977). Widely accepted types of recovery patterns in bilingual individuals with aphasia were given by Paradis in 1977. They are *parallel* (similar impairment and rate of recovery in both languages), *differential* (different levels of impairments and varied rates of recovery in languages), *antagonistic* (regression in one language and recovery in another language), *successive* (one language is recovered initially and then second language is recovered), *selective* (selective impairments in different languages), and *mixed* type (patient uses all languages to communicate). These patterns have been reported by several studies with more studies reporting parallel and differential recovery patterns in bilingual individuals with aphasia.

### 2.7.2. Language deficits in bilingual aphasia

Various studies in the past have concluded that L1 and L2 have overlapping cortical representation (Abutalebi, 2008; Perani & Abutalebi, 2005). However, the strength of overlapping between these two languages depend on several factors like proficiency level in each language, age of acquisition of each language and exposure levels in each language (Abutalebi & Green, 2007; Indefrey, 2006; Perani & Abutalebi, 2005).

The manifestation of clinical symptoms in individuals with bilingual aphasia vary in both severity and type of impairments, and recovery patterns in each language (Ansaldo, Marcotte, Scherer, & Raboyeau, 2008). Although major research on bilingual aphasia has focused on recovery patterns in these individuals, certain amount of research was also done on language deficits.

Differences in grammatical word class effects (noun-verb word retrieval) have been studied extensively in individuals with bilingual aphasia in multiple languages. Kremin and De Agostini (1995) have studied noun and verb naming using picture naming task in only L2 (Italian) of a Bergamac-Italian-German trilingual individual with left hemisphere lesion. Results revealed similar processing abilities for nouns and verbs in L2. However, this study has several drawbacks including testing only in L2 which is not sufficient to draw conclusions on noun and verb processing in bilingual individuals with aphasia, the subject's aetiology is unknown for aphasia other than lesion in left hemisphere and the validity of test items are not known. Sasanuma and Park (1995) have reported that greater word retrieval deficits were found in L2 than in L1, however, the performance in each language between noun and verb retrieval tasks is similar. Kambanaros and van Steenbrugge (2006) have studied noun and verb retrieval deficits in Greek-English bilinguals with anomic aphasia and results revealed that verbs were found to be more difficult than nouns in both languages irrespective of proficiency level. Hernandez, Costa, Sebastian-Galles, Juncadella, and Rene (2008) reported of more difficulties on retrieval of verbs than nouns in a Spanish-Catalan bilingual with primary progressive aphasia. Kambanaros (2010) have studied noun and verb naming in L2 Greek-English bilingual speakers with anomic aphasia. Results revealed significant deficits in retrieval of nouns than retrieval of verbs in spontaneous speech despite significant deficits on action naming in both L1 and L2. Bose and Chengappa (2000) have investigated the naming deficits in

Kannada-English bilinguals. They found that the performance was similar in both languages except on confrontation naming.

Tscirren, Laganaro, Michele, Martory, Pietro, Abutalebi, & Annoni (2011) have studied language and syntactic deficits in L2 late bilingual individuals with aphasia using Mississippi Aphasia Screening test (MAST: Nakase-Thompson et al., 2005) and Bilingual Aphasia Test (BAT: Paradis, 1987) and an auditory syntactic judgment task. Results revealed that the performance was similar across L1 and L2 on overall aphasia scores. On syntactic judgment task, four subjects with lesion in pre-rolandic area performed poorly in L2 than in L1. Sreedevi (2000) explored comprehension deficits in Tamil-English bilinguals with aphasia using Revised Token Test. Results revealed significant differences in language comprehension deficits in L1 and L2 with anomic aphasics performance being better followed by Broca's, Wernicke's and global aphasics.

The pattern of double-dissociation is also found in bilingual individuals with aphasia. Ibrahim (2008) had documented a case study on Arabic-Hebrew bilingual individual with aphasia, in which he reported of severe impairment in Arabic (L1) and mild language deficits in Hebrew (L2). He explained these dissociations between L1 and L2 are due to involvement of distinct cortical areas at neural level. Hegde, Subbarao and Bhat (2010) also found double-dissociation in their case study on Kannada-English bilingual individual with conduction aphasia. They found significant differences in performance between L1 and L2 on both lexical tasks and phonological tasks. However, the subject failed to recognize spelled words in both L1 and L2.

Bhan & Chitnis (2010) analyzed narrative discourse of a Telugu-English bilingual subcortical patient for lexical errors. Results revealed frequent semantic and phonemic paraphasias in both languages. Apart from these, the patient also exhibited dynamic misnaming, empty speech, circumlocution, semantic confusion and neologisms in discourse with subcortical lesion. Translation skills were affected in individuals with subcortical lesions along with mild motor and cognitive deficits.

George, Singh, Modayil, and Bhat (2010) have studied cross-linguistic naming performance in Kannada-Tulu bilingual aphasics using Boston Naming Test. Results revealed that bilingual individuals with Broca's aphasia performed better with phonemic cues followed by graphemic and semantic cues. However, the authors did not find any influence of cross-linguistic cueing on naming performance in bilingual aphasics. George and Mathuranath (2000) have reported better performance in L1 than L2 on various language tasks such as comprehension, repetition, naming and so on in a Malayalam-English bilingual patient with primary progressive aphasia. Similar type of result was also found in follow-up after one year, although there was a decline in overall language impairments with rapid decline in L2 than in L1. Ravi, Gnanavel, Vishnu, and Shyamala (2010) have reported better action naming performance in L1 than in L2 in Kannada-English bilingual individuals with aphasia on both accuracy and reaction time measurements. Mohan and Swapna (2010) have reported of varied amount of both recurrent and continuous perseverations in Kannada-English bilingual aphasics with more perseverations in L2 than in L1. Narang and Laskar (2010) have studied language deficits and translation abilities in 25 Assamese-English bilingual individuals with aphasia. Results revealed better performance in L1 than L2 on comprehension, expression, picture-word matching, writing, and reading comprehension tasks although the difference was not statistically significant for some tasks. On translation tasks, subjects performed better in tasks of L1 to L2 than L2 to L1 at word and sentence levels.

## 2.8. Sentence processing in monolinguals and bilinguals

Sentence processing involves a more complex mechanism compared to processing of words, as the listener or reader needs to identify the structures of a sentence and process them to understand the meaning of the whole sentence within few seconds. Few models such as the garden-path model (Frazier, 1978), and constraint-based satisfaction models of sentence parsing (MacDonald, 1994) have focused on explaining the strategies used in sentence interpretation. Garden-path model hypothesizes that the comprehension of sentences involves only computation of single syntactic analysis, whereas, constraint based theories assume that syntactic analysis is done based on all relevant information. The models of garden-path (Frazier, 1978) and constraint-based satisfaction (MacDonald, 1994) models were majorly focused on parsing strategies in sentence comprehension. Several studies were carried out to explore the nature of parsing strategies involved in sentence comprehension using methods such as eye-tracking, accuracy, speed of processing, and event-related potential studies. However, in certain circumstances such as under accuracy and speed measures, participants may not notice ambiguity or mis-parse the sentences. The garden-path (Frazier, 1978) and constraint-based satisfaction (MacDonald, 1994) models do not explain the processing of some of the passive structures of language and some ambiguous sentences.

The good-enough approach (GE) of sentence processing is aimed at explaining these circumstances in which the participant may settle for a parse that is in some way incomplete or underspecified, resulting in interpretation that is not faithful to the input (Ferreira & Henderson, 1998). The good enough approach to language processing assumes that listeners do not always engage in detailed processing of linguistic input, rather, our linguistic system has a tendency to develop shallow and superficial representations when confronted with some difficulty (Ferreira, Ferraro, & Bailey, 2002; Ferreira, & Patson, 2007). The major assumption of GE processing is that if the interpretation is incorrect, then it indicates that the analysis of syntactic structures has not taken place.

Ferreira et al. (2009) have conducted an experiment on twenty-eight participants using a visual paradigm and auditory input task of processing ambiguous and unambiguous stimuli using eye tracking method. The results revealed that the demands of the task affect processing of ambiguous sentences in visual contexts and supports good-enough approach of language processing.

Ferreira, et al. (2002) have found two major claims in support of good enough processing. They are involvement of shallow processing of sentence meaning and misunderstanding of sentences. These claims were found during comprehension and answering of few ambiguous sentences without analyzing the actual meaning of sentence which indicated that the processing of sentences can be shallow in nature. Further studies on processing of garden-path sentences by Ferreira, Christianson, & Hollingworth (2001); Ferreira (2003); Christianson et al (2003) have found that people not only misunderstand the sentences but they often fail to get the meaning of garden-path sentences. Results of event related potential studies done by van Herten, Kolk, and Chwilla (2005); Tabor, Galantucci and Richardson (2004) have found only P600 effect for syntactically anomalous sentences. However, semantic anomalies in sentences did not result in N400 indicating correction of sentence only in meaning but not for syntactic structures.

Harrington (2001) opined that the research on sentence processing is largely focused on the processes of structure building by mature speakers and that the learning and individual differences were less focused on. In contrast, research on the second language acquisition focused on explaining the way individuals acquire proficiency in L2. However, second language processing research at sentence level is more useful in understanding the cross-linguistic variations related to sentence structure. L2 sentence processing can be used as an indirect measure of understanding the interaction between the two languages in dealing with semantic and syntactic structures at sentence level in bilinguals.

Research on sentence processing in monolinguals and bilinguals has been conducted by using techniques such as eye-tracking, ambiguity resolution and so on. The research on sentence processing in adult speakers revealed that the adults make use of lexico-semantic structures and pragmatic aspects along with cognitive abilities to comprehend sentences with ambiguity (Adams & Gathercole, 2000; Nakano, Felser, & Clahsen, 2002; Thorton, MacDonald, & Gil, 1999). However, study by Williams (2006) revealed that this ability to make use of lexical-semantic structures and pragmatic aspects during parsing is reduced in non-native speakers. Booth, MacWhinney, and Harasaki (2000) in their study on children's ability in ambiguity resolution of sentences through reaction time, found that the children with high digit span scores exhibited faster sentence comprehension in both reading and listening modes which supported the role of cognitive aspects, especially the role of short memory abilities in sentence comprehension.

Several research studies in the past have found significant differences in both semantic and syntactic processing at sentence level between L1 and L2 through electrophysiological studies (Weber-Fox & Neville, 1996; Hahne, 2001; Hahne & Friederici, 2001). Friederici & Hahne (2001) reported that children as early as 7- and 8-year old have started using parsing strategies in sentence comprehension as similar to adults which was revealed through latency of N400 and P600 ERP components.

Results of various studies carried out to study the similarities and differences between L1 and L2 in processing morphological information have also reported differences in lexical and memory systems. For example, Ullman (2005) reported that in L1, declarative memory subserves mental lexicon and procedural memory subserves aspects of mental grammar. While in L2, learners tend to use declarative memory for functions that depend on procedural memory in L1 indicating use of declarative memory systems for processing grammar aspects of L2. Evidence from priming and ERP studies have also supported the view that different control systems are involved in processing of morphosyntactic structures of L1 and L2 (Clahsen, Luck, & Hahne, 2007; Hahne, Muller & Clahsen, 2006; Silva & Clahsen, 2008).

Felser, Marinis & Clahsen (2003) investigated the relative clause attachment preferences during processing of ambiguous sentences in children and adults using grammaticality judgment task comprising of 58 sentences. Results indicated an accuracy rate of 88% and 62%, for adults and children respectively. Results of reaction time measures showed shorter RTs for adult group than children group and statistical analysis revealed interaction between prepositions and attachment for both groups. The authors have concluded that semantic properties of preposition influence the online and offline relative clause attachment preferences in adults only. Authors also proposed that the differences in processing can be due to factors such as prosodic information in ambiguity resolution, frequency of exposure, and differences in working memory abilities between adults and children.

Studies on the cross-linguistic influences at the semantic, syntactic and phonological levels have provided major evidence in understanding the processing of languages in bilinguals (Chan, 2004). Grammaticality judgment tasks and sentence interpretation tasks are frequently used to study syntactic processing in cross-linguistic studies. Using these methods, differences have been found between early bilinguals and monolinguals in sentence interpretation tasks at syntactic level (Kilborn, 1989; Hernandez, Bates, & Avila, 1994; Liu, Bates, & Li, 1992). These studies found that monolinguals and bilinguals used different strategies in identifying the subject of a sentence. The strategies differed as a function of proficiency level, with dominant bilinguals tending to use strategies from only their dominant language, while the balanced bilinguals tended to use combined or different strategies that were effective for each of the two languages.

Evidence for differences in processing L2 through the L1 system comes from several research studies. Sentence comprehension or sentence judgment task (syntactic or semantic) in L2 is approached through a fully developed processing system from their L1 in bilinguals. Several studies using both behavioural (accuracy and RT measures) and objective methods (fMRI, PET) found differences in processing of syntactic information in L1 and L2 but not semantic information (Hahne, 2001; Hahne & Friederici, 2001; Kutas & Kluender, 1991).

Mack (1986) studied processing of semantic and syntactic structures in 10 English monolinguals and 10 French-English bilinguals. A total 104 word pairs of prime and target words in English were given to subjects and they were asked to judge whether the target word is related or unrelated to the primed word. In the first experiment, English semantic structures in English monolinguals and fluent early French-English bilinguals through reaction time measurements were studied. In semantic tasks, the results revealed that both monolinguals and bilinguals performed faster in response to related pairs, and slower in response to the nonsense pairs. It was also found that the reaction times of monolinguals were faster than those of the bilinguals in response to all word-pair types. In the second experiment on syntactic judgment task, the results revealed that monolinguals performed fastest in response to the scrambled sentences, while bilinguals performed fastest in response to the sentences in which phrases or morphemes were literally translated from French. The author concluded that the differences in performance were due to the interference of French in English tasks for the bilingual group. It was also concluded that bilingual linguistic interference is seen even among highly fluent early bilinguals which is a potentially unitary phenomenon manifested across components.

In order to determine if there are differences in sentence processing and in subsequent sentence recognition between L1 and L2, Sepanski and Li (2007) studied the sentence processing through accuracy and reaction time measurements in 40 late English-Spanish bilinguals at different proficiency levels in both their L1 and L2. They found a significant interaction between types of sentence change (meaning and form) and proficiency level, with the low proficiency group performing significantly worse when detecting meaning changes than the intermediate and high proficiency groups. These results suggest that the participants were more accurate at detecting English meaning changes than Spanish meaning changes, whereas they did not find any difference for form change in sentences on accuracy measurements. Analysis of reaction time data revealed that participants were faster in responding to sentences with meaning change compared to form change sentences, and participants were faster at responding to L1 (English) sentences than they were at responding to those of L2 (Spanish). The authors concluded that meaning-form relations in L2 word processing and sentence processing may be subserved by the same processing principles, both of which could be constrained by L2 proficiency.

Leong, Tsung, Tse, Shum and Ki (2012) studied the grammaticality judgment of Chinese and English sentences in a group of 118 non-native subjects of ethnic Indian and Pakistani origin who were learning Chinese at school. The authors found better processing of grammatically correct sentences than grammatically anomalous sentences in both languages. The overall accuracy rate was found to be lower in processing Chinese sentences than in processing English sentences. The results of this study sustained the hypothesis that L2 learners do not use syntactic information in L2 to such an extent as they do in L1. The other major outcome of this study was in relation to the effect of exposure and training in Chinese for over seven months period. The results of this study found that the subjects performed better in recent Chinese (trained as L2 in school and exposed in social context) language compared to English.

Several studies have been carried out in the past to explore the factors contributing to the sentence comprehension impairments in persons with aphasia (PWA). The speed of lexical activation is found to be one of the main factors contributing to the impaired sentence comprehension in persons with aphasia (Del Toro, 2000; Milberg & Blumstein, 1981; Thomson & Choy, 2009). It is also found that PWA exhibit incomplete access to word class information and are slow in integrating the words of sentence (ter Keurs, Brown, & Hagoort, 2002; Thompson & Choy, 2009). DeDe (2012) conducted a study to explore the effect of factors like word frequency and modality of stimulus presentation on sentence comprehension in aphasia. Results indicated that similar to typical individuals (Brysbaert, Lange, & Van Wijnendaele, 2000; Morrison & Ellis, 2000), the individuals with aphasia have exhibited difficulty in comprehending sentences with low frequency words than that of high frequency words, the extent being greater however. DeDe (in press) have also studied the performance of PWA on reading and auditory comprehension of sentences with subject and object clefts to explore the functioning of central linguistic processes. The author found that the individuals with aphasia exhibited more errors in sentences with object cleft than subject cleft in both auditory and reading modalities. Reaction time data analysis revealed that the individuals with aphasia showed longer response times for the verb segment in sentences in both modalities. These results concluded that the sentence comprehension impairments are similar in both auditory and reading modalities, suggesting sentence comprehension impairments more at central linguistics processes than that of modality specific deficits.

Peach, Canter and Gallaher (1988) studied comprehension of sentences in individuals with anomic and conduction aphasia using picture-pointing auditory and reading comprehension tests. Results revealed that both groups performed better on comprehension tasks. The authors also found a moderate level of correlation for responses in auditory and visual modalities for anomic group and a strong correlation observed for conduction aphasia group indicating good relation between auditory and reading comprehension. Studies on reading comprehension in aphasia have also revealed influence of contextual factors like preceding and following components of sentence (Germani & Peirce, 1992). Duman, Altnok, Zgirgin and Bastiaanse (2011) carried out a study on auditory sentence comprehension in Turkish individuals with Broca's Aphasia to explore the effects of word order and case. Results revealed that the individuals with aphasia comprehended sentences better when both word order and case information was provided suggesting presence of integration deficits during syntactic comprehension in individuals with aphasia.

## 2.9. EVENT RELATED POTENTIALS (ERPs)

Till late 19$^{th}$ century, neurosurgeons, neurophysiologists and other researchers depended upon the data of clinical population especially of individuals with aphasia, starting from Paul Broca (1861) to understand the language processing in humans. Several theories on neural representation and psycholinguistic theories of language processing and language organization at brain level have been formulated with the data on clinical population. In 1980's and 1990's, several new imaging and nonimaging techniques such as PET, fMRI, EEG and MEG have been developed and the research on neurolinguistics of language has blown up with major studies and breakthroughs in understanding language organization and processing at neural level. Although, PET and fMRI are reported to give more accurate spatial information about site of activation during processing of language tasks, they lag in providing temporal information of language processing. As language processing is quicker and happens within few milliseconds, it is also important to understand time course of language processing along with spatial information to completely understand language organization and processing. Electrophysiological methods, specifically, electroencephalogram (EEG) and event related potentials (ERPs) have been found to be accurate and cost-effective tools in understanding the temporal information of language processing. Although, these techniques are good to understand temporal information, they do not provide spatial resolution. Hence, these methods are preferred over hemodynamic methods in understanding the temporal course of language processing. These methods have been widely used in both language and cognitive research over the years.

Electroencephalography (EEG) is developed on the basis that at neuron level, electrical potentials are generated and transmitted to process the information during every activity and EEG is designed to measure these electrical potentials. The changes in voltages of electrical potentials are drawn over a time course to understand the processing of information. As the name indicates, the event related potentials are the variations in potentials followed by an event or stimulus, which may be a cognitive or language stimulus. The voltage changes to specific stimulus are called as event related potentials. ERPs provide dynamic information of brain activity during reception and processing of sensory information as well as processing of higher cognitive functions including language, attention, memory and so on (Duncan, Barry, Connolly, Fischer, Michie, Naatanen, Polich, Reinvang, van Petten, 2009). An ERP component is defined by its polarity (positive or negative), latency (in milliseconds) and scalp distribution. Apart from providing good temporal resolution, these methods are noninvasive and are useful in understanding the pathological language and cognitive processing.

Latencies of ERPs represent the time course of processing of information or event in milliseconds, amplitude level indicate the extent of allocation of neural resources to specific cognitive processes (Duncan et al. 2009). ERPs are great techniques which provide information about processing of language, and cognition, they also complement the information elicited by behavioural methods such as accuracy and speed of processing. Any abnormalities in latencies or amplitude levels indicate pathological conditions and ERPs are being used widely in clinical research in studying pathological language and cognitive processing in patients with stroke, aphasia, dementia, traumatic brain injury, cognitive decline, childhood language disorders, coma, and psychiatric disorders (Baldeweg, Klugman, Gruzelier, Hirsch, 2002; Brown, Clarke, Barry, McCarthy, Selikowitz, Magee, 2005; D'Arcy, Marchand, Eskes, Harrison, Phillips, Major, et al, 2003; Duncan, Morihisa, Fawcett, Kirch, 1987; Hagoort, Brown, Swaab, 1996; Marchand, D'Arcy, Connolly, 2002; Swaab, Brown, Hagoort, 1997).

The major ERP components that are used in cognitive and language research include P1, N1, MMN, P300, N400, and P600. These potentials/components are defined based upon their latency range and polarity (negative or positive). Although, all these components are used in studying language and cognitive processing, N400 and P600 are specifically used for studying language processing including semantics and syntactic processing.

*P1* is a positive peak occurring at around 90-130ms post-stimulus presentation (Luck, 2005). P1 is largest at lateral occipital electrode with and early portion of P1 wave arising from areas in middle occipital gyrus and later portion arising from fusiform gyrus (Di Russo et al., 2002). Any variations in stimulus parameters result in P1 peak and is reported to be more sensitive for spatial attention (Hillyard, Vogel, & Luck, 1998) and to the subject's state of arousal (Vogel & Luck, 2000).

*N1* is a negative peak occurring at around 90-130ms post-stimulus presentation with maximum amplitude at 100ms. Subcomponents of N1 include a frontocentral component that peaks around 75 ms, a vertex maximum potential around 100 ms, and a more laterally distributed component peaking around 150 ms (Naatanen & Picton, 1987). These subcomponents appear to be generated in the auditory cortex on the dorsal surface of the temporal lobes and superior temporal gyrus (Luck, 2005). The N1 peak is also reported to be sensitive to attention (Woldorff et al., 1993).

The *mismatch negativity* (MMN: Naatanen et al., 1978) component is elicited when subjects are exposed to any discriminable change in the stimuli which can be tones or speech sounds in frequency or intensity parameters (Duncan et al., 2009; Luck, 2005). MMN component represents an automatic process that detects a difference in incoming stimuli and the sensory memory trace of preceding stimuli (Duncan et al., 2009). MMN has been a very useful component in assessing clinical population as it does not require attention or response of subject. The commonly used paradigm for eliciting MMN is *oddball stimuli paradigm* in which an odd stimuli is presented occasionally in alike stimuli presentation (eg., p p p p p p *b* p p p p p p *b* p p p p p). The mismatch in stimuli results in negativity at around 160-220 ms with largest amplitudes at midline central electrodes. Bilateral auditory cortices and right frontal cortex are the possible generators of MMN component (Giard et al., 1990). Any change in involuntary attention switching produces frontal MMN subcomponent indicating the role of frontal cortical mechanisms involvement in attention (Naatanen and Michie, 1979; Rinne et al., 2000).

The *P300* (Sutton et al., 1965) is a large, broad, positive component with maximum amplitude at around 300 ms or more after onset of a rare, task-relevant stimulus (Duncan et al., 2009). Squires, Squires, and Hillyard (1975) identified two components of P300, a) *P3a* being frontally maximal elicited with onset of rare, *non-task relevant* stimulus and b) *P3b* being a parietally maximal component with onset of *task-relevant* stimulus. However, unlike MMN component, P300 requires subject's attention towards stimulus. The factors like temporal probability and global probability (Gonsalvez and Polich, 2002; Picton and Stuss, 1980; Woods and Courchesne, 1986), sequence of stimuli preceding the eliciting stimulus (Squires et al., 1976), salience of the eliciting stimulus (Keil et al., 2002; Yeung and Sanfey, 2004), and attention levels (Kramer et al., 1985) affect the amplitude of P300 component. P300 has been effectively used in assessment of dementia and cognitive impairments (O'Donnell et al., 1992), schizophrenia (Duncan et al., 1987b; Price et al., 2006), mood disorders (Kaustio et al., 2002), TBI (Duncan et al., 2003).

The *N400* (Kutas and Hillyard, 1980) component is a negative going wave with largest amplitudes over central and parietal electrodes at around 400 ms post onset of stimulus. N400 is elicited when a semantically violated stimulus is presented. N400 is also observed for different types (abstract vs concrete, open vs closed class, frequent vs infrequent) of words (Boddy, 1986; Rugg, 1985). N400 is larger at right hemisphere electrodes and appears to be generated primarily in left temporal lobe (Luck, 2005; Van Petten and Luka, 2006). N400 component is seen for semantic violations in printed, spoken and signed language (Kutas et al., 1987; Holcomb and Neville, 1990; Connolly et al., 1992). The amplitude of N400 is sensitive to lexical characteristics of the target words (Van Petten and Luka, 2006; Holcomb et al., 2002; West and Holcomb, 2000). N400 is one of the major components used in language experiments in both typical individuals and clinical population over the years. N400 component is used in individuals with stroke (Connolly and D'Arcy, 2000; D'Arcy et al., 2003; Hagoort et al., 1996; Marchand et al., 2002), dementia (Iragui et al., 1996; Van Petten and Luka, 2006), child language disorders (Bergmann et al., 2005; Grossi et al., 2001; Radeau et al., 1998).

P600 or late positive syntactic shift is a positive peak occurring at around 600 ms for syntactically violated stimuli (Osterhout and Swinney, 1989; Osterhout and Holcomb, 1990; 1992; Hagoort, Brown and Groothusen, 1993). The P600 was initially found in sentences with some grammatical errors and phrase structure violations. Later research studies showed that the P600 is also found in syntactic ambiguity (Gouvea, Philips, Kazanina and Poeppel, 2010; Osterhout et al., 1994), and in cases of long-distance dependency (Gouvea et al., 2010; Kaan et al., 2000). The P600 is mainly related to sentence reanalysis, repair processes and syntactic integration (Gouvea et al., 2010).

## 2.10. LANGUAGE PROCESSING IN NORMAL BILINGUALS – ERP STUDIES & BEHAVIOURAL STUDIES.

Ardal, Donald, Meuter, Muldrew and Luce (1990) have conducted a study on 24 fluent bilinguals with English as second language and 24 monolinguals to study brain responses to semantic incongruities using event related potentials. Subjects were asked to read 80 English sentences which included both correct and incongruent sentences during which ERPs were recorded from six (Pz, Oz, P3, P4, F3 & F4) electrode sites. Results revealed that the mean latency of N400 peak at parietal sites is found to be 390msec and at frontal sites, it is 408msec. N400 peak latency was earlier and shorter in L1 than in L2 in bilinguals to semantic incongruities indicating bilingual individuals process L1 faster than L2 and reduction of automaticity. Analysis of N400 peak amplitudes revealed a significant difference between L1 and L2 in bilinguals with L1 having higher amplitude levels for semantic incongruities with varied amplitude levels of N400 at frontal and parietal sites indicating the differences in fluency levels in each language. These differences in latency and amplitude levels of N400 were attributed to the factors of current usage and differences in fluency levels in both mono and bilinguals.

Weber-Fox and Neville (1996) have studied 61 adult Chinese-English bilinguals who were exposed to L2 at different points in development (1-3, 4-6, 7-10 and after 16 years of age) to explore the maturational constraints on development of functional specializations of distinct subsystems within language, specifically semantics and syntactic structures using event related potentials and behavioural measures. Analysis of ERP responses to semantic anomalies revealed similar to results of studies on monolinguals, an increased negativity was found in response to semantic anomalies with a maximum at approximately 400 msec. A delay in N400 peak latency was found only for subjects who were exposed to English after 10 years of age and who were rated as having less proficiency in L2, i.e., 11-13 and >16 groups indicating slight slowing in processing of semantic anomalies. These results were similar to that of Ardal et al., 1990 who reported a slight delay in latency in less fluent bilinguals. Analysis of mean amplitude levels revealed a significant effect for sentence type for all bilingual groups except >16 group. Results also revealed that the 1-3 years group has maximal amplitude towards posterior regions with slightly larger effect over the right hemisphere. 4-6, 7-10, and 11-13 age groups also have got maximal amplitude towards posterior regions with no significant differences between hemispheres indicating the significant effect of handedness on N400. Analysis of ERP responses to syntactic violations revealed that 1-3, 4-6, and 7-10 groups showed late positive shifts to phrase structure violations starting at around 500 msec latency that were similar to earlier studies on monolinguals. There was no late positive shift was evident between 500-

700msec for the group of 11-13, but a very late increase in positivity beginning round 700 msec was observed. No late positive shift was observed for the group of >16. These results indicated that a delay in exposure to language results in decreased accuracy and altered ERPs for phrase structure violations. These results indicated that the late learners of L2 do not process the syntactic information similar to that of early bilinguals and also late bilinguals may not attempt to ‘patch up’ the anomalous sentence as that of early bilinguals.

Hahne and Friederici (2001) have studied semantic and syntactic processing at sentence level using ERPs on 20 late Japanese-German bilinguals. Semantic violations resulted in a significant N400 effect between 400 to 700 msec latency in bilinguals. The N400 effect was found over posterior sites bilaterally and also over anterior and central regions of the right hemisphere. Syntactic violations in stimuli resulted in a right anterior negativity and a reverse “P600-effect” in the late time window of 700 to 1100 msec. However, the responses to syntactic violations were not consistent and reliable compared tp correct sentences. The absence of early left anterior negativity in L2 learners indicated poor first-pass parsing in these individuals when compared to the native speakers. The absence of P600 or late positive shift indicated absence of syntactic repair processes for syntactically violated sentences in L2 group.

Kotz (2001) has used lexical decision task and ERPs to study the word recognition in 32 early fluent Spanish-English bilinguals. Stimuli included five types of primed words, associatively related, associatively unrelated, categorically related, categorically unrelated and word/pseudowords in both Spanish and English. The analysis of ERP data revealed no significant difference in mean amplitude of N400 between languages and no main effect of semantic relation. The results of ERP data indicated an associative and categorical N400 priming effect which is independent of language in contrast to reaction time data which indicated only associative priming. These results have supported the revised hierarchical model (Kroll and Stewart, 1994) and concluded that word recognition is similar in L1 and L2 in early fluent bilinguals.

De Brujin, Dijkstra, Chwilla, and Schriefers (2001) have studied effects of language context on word recognition using reaction time measures and ERPs. Study included twenty Dutch-English bilingual speakers and lexical decision task with priming was used in eliciting responses in both languages. Stimuli were 312 triplets consisting of non-words and/or words. The analysis of ERP data revealed a significant N400 effect for first and second items between 400-600 msec latency and third item elicited N400 between 800-1000 msec. However, the amplitude of second N400 for item 3 varied by relatedness of the stimuli. This effect of relatedness was present at most electrodes with semantically related words showing less amplitude levels and semantically unrelated words elicited higher amplitudes. However, no effects of language of stimuli were seen for the N400 indicating a strong bottom-up role in word recognition by bilinguals and thus supporting bilingual interactive activation model (Dijkstra and Van Heuven, 1998).

Hahne (2001) studied processing of semantic and syntactic violations in German language in German monolinguals (L1 group) and late Russian-German bilinguals (L2 group) using event related potentials. Sentences with semantic violations in German language have elicited N400 effect in both the groups with reduced amplitude and longer latency in the L2 group. The syntactic violations have elicited early left anterior negativity (ELAN) only in L1 group but not in L2 group indicating that the processes are highly automatic in native listeners but not in L2 group. However, late positivity (P600) was observed in both the groups indicating similar syntactic integration and repair processes in both groups.

Proverbio, Cok, and Zani (2002) studied processing of syntactic and semantic violations in Italian monolinguals and Italian-Slovenian bilinguals during reading comprehension of sentences. Electrophysiological recordings were done simultaneously during the task and recordings were analyzed for early and late potentials. Results revealed prominent early negative potentials across occipito-temporal regions indicating involvement of areas assumed to process orthographic processing for Slovenian language and the potentials were bilaterally distributed for Italian language. Semantic violations in both L1 and L2 elicited similar N400 responses with greater response over left hemisphere than right hemisphere. However, syntactic violations elicited P600 components with bilateral activation for Italian stimuli and right hemispheric activation for Slovenian stimuli although the bilingual subjects have acquired both languages at very early age and proficient in both languages. The results of this study also revealed differential processing of the two languages in high proficiennt bilinguals which was attributed to some very subtle, hard-wired, differences in linguistic proficiency of the two groups.

Moreno and Kutas (2005) have explored the processing differences in Spanish-English bilinguals in L1 and L2 by considering the factors like age of acquisition, proficiency levels. A total of 48 sentences in each language with 24 correct and 24 semantically anomalous sentences were presented to subjects in visual mode and subjects were asked to judge whether the sentence is correct or incorrect. Electrophysiological recording was done using 26 electrode sites during the semantic judgment task. Results showed that semantically anomalous sentences elicited higher centro-parietal negativity between 200-600 msec in both languages. N400 peak latency was delayed for semantic anomalous sentences in nondominant language compared to dominant language. The factors such as late exposure, language dominance, and vocabulary proficiency were highly correlated with the slowing of N400 latency in nondominant language.

Balaguer, Sebastian-Galles, Diaz, and Rodriguez-Fornells (2005) have studied the effect of similarity of languages on processing of morphological structures in two languages in early Catalan-Spanish bilinguals. Regular (similar structure in both languages) and irregular (different word structures) type of verbs were presented in repetition paradigm in Spanish language to high proficient bilinguals. No significant differences were found in amplitude of N400 between L1 and L2 for regular verbs. However, significant difference was found in amplitude of N400 between L1 and L2 for irregular verb types indicating that the similarity in languages help in processing similar structures but not for dissimilar structures.

In an attempt to study whether bilinguals use native language to comprehend second language, Thierry and Wu (2007) have conducted an ERP study on 15 Chinese-English late fluent bilinguals and 15 monolinguals on a semantic relatedness task exclusively on English and Chinese word pairs. Results revealed reduced mean N400 amplitude for semantically related targets compared to unrelated targets and for targets that shared a Chinese character with the prime through translation as compared to targets with no character repetition. Combined behavioural and electrophysiological results indicate that automatic translation process is used by late bilinguals. These results also supports parallel, language-nonselective activation models of bilingual word recognition.

Mueller, Hirotani, and Friederici (2007) have studied the processing of case markers in native and non-native learners of Japanese using ERPs. Results indicated presence of N400-P600 biphasic pattern for only native speakers and negativity was preent in learners only for double nominative violations with different topographical distribution. Results of the study furtehr indicated that the native speakers use case markers for syntactic structure building during sentence processing. However, the results of non-native speakers indicated the use of phonologically salient nominative case markers during sentence comprehension.

Weber and Lavric (2008) found N400 component in response to syntactic anomalies only in second language in their study on German-English bilinguals during reading comprehension of sentences. Results revealed a significant P600 effect for morphosyntactic violations in both L1 and L2. However, these morphosyntactic violations resulted in N400 component in L2 but not in L1. These results indicated that the morphosyntactic structural analysis in second language depends upon lexico-semantic system which is not seen in proficient or native language.

Leikin (2008) investigated differences in amplitudes and latencies in English-Hebrew and Hebrew-English bilinguals during reading comprehension of sentences with syntactic violations. Ananlysis of results showed P300 and N400 components during processing of predicates in both languages indicating the involvement of stimulus classification, short term memory and morphosemantic processing. Greater positive amplitudes at both early and late latencies including P600 component was observed during processing of syntactic violations especially for word order changes. Overall results concluded that the both bilingual groups utilize the mixed strategy for identifying the grammatical role of words in both languages and this is reported to vary upon the characteristics of participants in terms of age of acquisition and level of exposure in each language.

Studies were also done to understand the strategies used by bilinguals in L1 and L2 in recent years. Guo, Guo, Yan, Jiang, and Peng (2009) have used ERP technique to investigate the strategies used by native English speakers and individuals learned English as their L2 during reading comprehension of sentences with verb sub-categorization violations. These syntactic violations elicited P600 effect only in native English speakers but not in L2 learners. However, an N400 effect was observed in L2 learners indicating different strategies used by native and L2 learners in processing of syntactic structures. These results indicated that the L2 learners are more responsive to semantic information to process verb sub-categorization violations. Topographic analysis of electrophysiology data revealed that P600 in native speakers was distributed broadly and N400 was distributed laterally over posterior and anterior regions.

Midgley, Holcomb, and Grainger (2009) have conducted three experiments using ERPs to investigate the language effects in bilinguals. Study involved three groups of subjects, English-French bilinguals, French-English bilinguals and proficient French-English bilinguals and they were given reading task of words in both languages. Results of experiments one and two showed a large broadly distributed N400 in both French-English and English-French bilingual groups in L1. Although N400 was observed in L2, it is only at centro-posterior sites with reduced N400 effect in anterior sites. Third experiment showed no significant differences in N400 peak latency and amplitudes between L1 and L2 in near equal proficient bilinguals indicating that N400 effect reflects the competence in L2, in which smaller N400 effects are found in low proficient bilinguals.

Moreno, Bialystok, Wodniecka, Alain (2010) have studied processing of anomalous sentences in form and meaning on 16 English monolinguals and 16 bilinguals using ERP and behavioural methods using sentence judgment task. Participants were asked to read a total of 120 sentences in four sets (correct, syntactically incorrect but meaningful, semantically anomalous but grammatical, and syntactically and semantically incorrect) and asked to judge whether the sentence is acceptable or grammatically correct or incorrect. Results of electrophysiological recordings revealed a significant N400 and P600 effects for semantic and syntactic violations respectively. Along with P600, early left anterior negativity (ELAN) was also elicited for syntactically violated sentences. The results also revealed that left anterior negativity (LAN) for syntactic processing in bilinguals depend upon involvement of executive functioning along with other factors such as age of acquisition and L2 proficiency. It was also found that larger N400 was seen for semantically incongruent words than to semantically congruent words in sentences with equal amplitudes and latencies of N400 in both mono and bilinguals. However, unlike N400, mean amplitudes of P600 were smaller in bilinguals than in monolinguals. These differences were found to be due to involvement of control mechanisms in bilinguals. In both tasks, bilateral representation was found in bilinguals for both the tasks and left lateralization was observed in monolinguals.

Altvater-Mackensen and Mani (2011) have conducted an ERP study of the sentence processing in German-English bilinguals to understand the cross-lingual phonological similarity effects on bilingual word recognition. Study included 10 German-English bilinguals who acquired L2 before the age of 6 years (early bilinguals) and eight German-English bilinguals who acquired L2 after the age of 6 years (late bilinguals) who listened to a total of 180 sentences (90 with German words as target words and 90 with German pseudowords) in which words are either cross-lingual homophones (German words that are phonologically close to English) or German words that have no relation to English. Study also included a visual paradigm in which subjects are asked to identify the object and press the corresponding button during which the sentences are presented and ERPs were recorded from 32 electrodes. Analysis of electrophysiology data revealed the amplitude levels were less for related conditions than for unrelated conditions between 500 to 1000 msec. The results also revealed significant differences for early and late bilinguals, where early bilinguals showed more positive N400 effect for homophones and related words compared to unrelated words indicating facilitation effect for the recognition of cross-lingual homophones. By contrast, late bilinguals did not show differences in N400 effect for cross-lingual words suggesting that bilinguals do not automatically activate words from both their languages during word recognition in sentence comprehension.

However, in a study by Zawiszewski, Erdocia and Laka (2011) on Spanish-Basque bilinguals during processing of verb agreement violations, word order violations and case morphological violations, they reported that when the similar grammatical structures are present in both languages, the verb agreement processing do not reveal differences between native and non-native speakers. However, case morphological violations revealed significant differences in electrophysiological responses between native and non-native speakers indicating the presence of effect of linguistic transfer from native language, Spanish. The word order violations also elicited subtle variations between the groups indicating usage of different strategies in processing native and non-native languages. These results indicated that the different components of language are processed differently in native and non-native languages by bilinguals.

Geyer, Holcomb, Midgley, and Grainger (2011) have studied repetition priming effects and translation processes during language processing in Russian-English proficient bilinguals. These subjects were presented with words in Russian and English languages in a mixed language lexical decision task and repetitions were presented on subsequent trials. Results revealed a robust ERP priming effects for target words with repetition in both languages at early latencies (150-300 msec) and late latencies (N400). Translation priming effects were also observed along with repetition priming in both languages and no significant differences were found between the two languages.

Cheng, Zhang, Koerner, and Windsor (2012) have studied morphosyntactic processing in English monolinguals and Chinese-English bilinguals using ERPs during grammaticality judgment task. Authors found significant differences between grammatical and ungrammatical sentences in both early and late potentials. However, P600 effect was not consistently observed across all the types of morphosyntactic violations in bilinguals indicating differential processing for different syntactic structures in bilinguals. Differences in P600 effects were also observed between L1 and L2 in bilinguals and this was assumed to be due to late acquisition of L2.

Braunstein, Ischebeck, Brunner, Grabner, Stamenov, and Neuper (2012) have presented 50 sentences ending in high or low probability cloze words, or semantically incongruent words visually to twenty German-English bilinguals with varied proficiency levels. The results indicated larger N400 effects for sentences ending with incongruent words than with low probability words follwoed by high probability words with maximum activity in centro-parietal region. This study also found larger N400 effects over right hemisphere indicating the activation of right hemisphere in processing of semantic violations in bilinguals. Between L1 and L2, the mean N400 latencies were longer for L2 than L1 for only low proficient bilinguals for low probable words indicating slower processing in these individuals.

### 2.11. Language processing in bilingual aphasics – ERP studies. – 8 studies

Although vast number of research studies have been conducted using ERPs to study language processing in bilinguals, few studies have also been done on studying language processing in pathological conditions including aphasia. However, the number of studies using ERPs is limited in bilingual individuals with aphasia.

Becker and Reinvang (2007) have conducted a study using ERPs to study the syllable detection in individuals with aphasia and effect of impaired speech sound processing for auditory comprehension deficits. The study included 10 subjects with moderate level, 10 subjects with severe level of auditory comprehension deficits and 11 healthy control subjects. Results revealed a significant reduction in amplitudes of N1 and N2 peaks indicating auditory comprehension deficits and deficits in primary stimulus analysis skills. However, no significant reduction in the amplitude of P300 peak among subjects with aphasia indicated good sound syllable discrimination skills. Topographical analysis of results indicated differential activation patterns in individuals with moderate and severe levels of auditory comprehension deficits. Severe aphasics showed a lateralization to contralesional hemisphere during early processing and symmetrical activation for later ERPs. Whereas, moderate aphasics showed more symmetrical activation in early processing and differential activation in late ERP components. These results indicated that the individuals with aphasia have compensational speech sound processing in syllable detection, they still exhibit deficits in more complex tasks. These differences in processing levels vary depending on site of lesion, post onset duration, task specific.

D'Arcy, Marchand, Eskes, Harrison, Phillips, Major, et al (2003) have used electrophysiological measures to assess language function in individuals with stroke and correlated with neuropsychological test scores. 10 subjects with left hemisphere stroke were assessed using Peabody Picture Vocabulary Test-Revised (PPVT-R; Minnesota: American Guidance Service, 1981) as part of neuropsychological assessment. ERPs were recorded during a computerized PPVT-R, in which congruent or incongruent spoken words were used. Results of neuropsychological test batteries have revealed significant deficits in receptive and expressive language skills in all the participants. Results of ERP analysis revealed PMN and N400 peaks for incongruent words with mean latency of 507 ms for N400 peak. Topographical analysis revealed significant centro-parietal activation with largest amplitudes at Pz for incongruent words. Correlational analysis revealed high correlation between results of neuropsychological tests (PPVT-R) and ERP data. The results of this study provided strong support for using ERPs as an objective tool to study language deficits especially semantic deficits in individuals with stroke to understand the neural mechanisms involved in language processing following stroke.

Wilson, O'Rourke, Wozniak, Kostopoulos, Marchand, and Newman (2012) have studied the effect of intensive language therapy in 15 individuals with aphasia followed by stroke using electrophysiological measures. Intensive language therapy was given by using InteRACT program for duration of four weeks involving language comprehension, production, reading and writing, and communication skills. ERP recordings were done during a picture-name matching task during pre and post therapy. On neuropsychological test batteries, more than half of the participants showed significant improvement and few participants have showed improvement in communicative skills. Topographical analysis of ERP waveforms revealed differential scalp distribution, with higher amplitudes over right hemisphere during pre-therapy and with higher amplitudes over left hemisphere during post therapy. However, there were no significant differences in amplitude levels of N400 component between pre and post therapy sessions. These results indicated differential neural generators of N400 in pre and post therapy conditions after intensive language therapy.

Swaab, Brown and Hagoort (1997) have used electrophysiological measures to assess spoken sentence comprehension in 14 Broca's and Wernicke's aphasics and 12 healthy individuals. Subjects were presented with half correct sentences and half anomalous sentences. N400 component was measured to two sentence conditions. Results revealed no significant differences in latency and amplitude of N400 component between healthy controls and aphasic subjects with mild comprehension deficits. However, the results revealed significant differences in latency and amplitudes of N400 component with reduction and delay in amplitudes in aphasics with moderate and severe comprehension deficits. This delay and reduction in amplitudes of N400 component indicated deficits at integration level of lexical information in sentence comprehension.

Justus, Larsen, Yang, Davies, Dronkers, and Swick (2011) have studied processing of regular past-tense morphology in 11 subjects with damage to Broca's area using electrophysiological measures. 600 Prime target pairs including regular, irregular, pseudopast and orthophono stimuli were presented to both typical and clinical population. Electrophysiological results revealed N400 effect for unprimed trials compared to primed trials for all four word types. Although significant differences were seen in behavioural data between healthy controls and clinical population, ERP effects of priming task were similar for regular and irregular verbs for both clinical and healthy subjects indicating impairments in behavioural data were not result of impairments of lexical priming, instead the result of post-lexical events related to segmentation, and cognitive control.

Electrophysiological measures have also been used in assessment of language functions in primary progressive aphasia (PPA) disorder. Giaquinto and Ranghi (2009) have examined word recognition abilities in a subject with PPA in a longitudinal study. N400 component revealed significant delay in peak latency by 300 ms and also reduction in amplitude in N400 peak. A follow up evaluation of word recognition skills after one year revealed further delay in peak latency and reduction in amplitude, and after two years, the N400 component was disappeared. These results indicated significant deficits in lexical access skills of individuals with PPA in later stages. This study also concluded that ERPs can be used as tool for diagnosis and monitoring of cognitive decline and language dysfunction in individuals with degenerative disorders.

Friederici, Cramon and Kotz (1999) have studied processing of semantically violated, syntactically violated sentences in healthy subjects, subjects with left hemisphere cortical lesions and subjects with left subcortical lesions using event related potentials. ERP components of N400 for semantically violated sentences and ELAN and P600 components for syntactically violated sentences were recorded from all three groups of subjects.

Results revealed normal responses for ERP components in healthy controls and subjects with left subcortical lesions. Whereas, in subjects with left frontal cortical lesions, N400 component was attenuated and only P600 component was observed. However, ELAN component was absent indicating deficits in automatic first pass parsing processes in subjects with lesions in left frontal cortical areas.

Hagoort, Brown, and Swaab (1996) have studied lexical semantic processes in individuals with left hemisphere lesions with aphasia and right hemisphere lesions without aphasia. Two types of word pairs were presented to two groups of subjects and ERPs were recorded. Results revealed typical N400 component in individuals with right hemisphere lesions and also in left hemisphere lesions with mild comprehension deficits. Whereas, the N400 effect was reduced in individuals with left hemisphere lesions with moderate to sever level of comprehension deficits. These results indicated that the deficits in aphasic subjects are due to impairment in integrating word meanings into an overall meaning representation.

Ter Keurs, Brown, Hagoort and Stegeman (1999) have studied word class information processing in typical individuals and in individuals with Broca's aphasia with agrammatic comprehension using electrophysiological measures. Subjects were presented with open- and closed-class words during which ERPs were measured. Results revealed that the typical individuals showed clear differences in processing of open and closed class words compared to that of individuals with Broca's aphasia in both early and late components. The results indicated that the agrammatic comprehension deficits in aphasia may be primarily due to delayed access to word class information.

## Need for the study

As seen in the review, several studies have been carried out using neurolinguistic, neuroimaging and behavioural methods in both normal and brain damaged individuals. However, most studies are inconclusive or inconsistent in their findings. There are very few studies which provide data on the impact of individual variables on language organization and processing in bilingual brain. However, much research is still needed to put forth any consistent theory on the foundations of bilingualism. The lack of methodological convergence regarding experimental tasks, design or sample's characteristics has made it hard to draw conclusions and postulate theoretical explanations. With advancement in technology, now it is possible to study neuroanatomical, neurofunctional, and neuropathological correlates of language processing in typical and brain damaged individuals.

The basic question in bilingual research on whether the two or more languages used by bilinguals are processed by same neural structures is still mystifying. Hence, more studies are required on studying the influence of individual factors and interaction between languages besides throwing light on cognitive functions in cortical organization of bilinguals.

A better understanding of the cerebral organization and functioning of each structure will contribute to theoretical perspectives on bilingual's brain. This will in turn provide information to rehabilitation sciences and neuropsychology about the normal and abnormal language processing in bilinguals, which will further help in improving assessment and intervention methods for the management of atypical population.

India, in spite of being the largest multilingual nation in the world, witnesses a dearth of studies on cortical representation of two languages in bilingual brain. Considering the extent of bilingualism in India, researchers across the world are actually looking for more studies from Indian subcontinent.

Therefore, there is a huge need to study the language processing aspects in Indian languages. The most common technology used in bilingual language processing research is functional magnetic resonance imaging. However, when investigating language and cognitive functions in which temporal information is very important, this fMRI has disadvantages. fMRI technique allows researchers to sample brain activity data only on large frames of time measurement. In order to localize the activation in cortical areas, event related brain potentials have become very useful in studying the online processing of information in brain. This method permits direct observation of information processing at different levels of analysis, and can provide crucial information by means of real time imaging of neural system's responses to sensory stimulation (Bentin, 1989). Therefore, the present research makes use of ERP technique to study the language processing in two languages in typical and atypical bilinguals.

**Aim of the study**

The present study is aimed at investigating the cortical representations and neurofunctional mechanisms of language (syntactic and semantic components) processing of Kannada (L1) and English (L2) languages in persons with bilingual aphasia and normal/typical bilingual individuals.

## Objectives of the present study

The objectives of the present study are three fold:

1. To study whether the same cortical regions mediate two languages in individuals with bilingual aphasia.
2. To explore neural representations of L1 and L2 in normal bilingual individuals.
3. To explore the impact of brain damage on language processing in L1 and L2.

## Hypotheses to be verified:

The following null hypotheses have been formulated for verification in the present study.

1. There is no statistically significant difference in the processing of first and second languages in typical bilinguals with respect to cortical representation.
2. There is no statistically significant difference between syntactic and semantic processing in typical bilinguals.
3. There is no statistically significant difference in language processing between typical individuals and individuals with aphasia.

# CHAPTER 3

# METHOD

The aim of the present study was to investigate the cortical representations and neurofunctional mechanisms of language (syntactic and semantic components) processing of Kannada (L1) and English (L2) languages in persons with bilingual aphasia and normal bilingual participants.

## 3.1. Participants

A total 40 Kannada–English bilinguals constituting two groups (group I and group II) participated in the present study.

### Inclusionary criteria

*Group I (aphasia group)* consisted of 20 Kannada-English bilingual participants with anterior aphasia (PWA) (either Broca's or Anomic type) followed by CVA who were diagnosed by speech language pathologist using Western Aphasia Battery–Kannada (Chengappa & Ravikumar, 2008) and neurologist. Sample size was decided based on the availability of Kannada-English bilingual participants with intact reading abilities. All the participants were right handed pre-morbidly and native speakers of Kannada (L1) language and learned English (L2) as second language. All the participants had minimum of 15 years of formal education. International Second Language Proficiency Rating Scale (ISLPR: Wylie & Inghram, 2006) was used to assess the language proficiency in second language. Pre-morbid ISLPR ratings for L2 of the participants were collected from family members/care givers. Socio economic status scale (Venkatesan, 2009) was used to assess the socio economic status of the participants. All the participants were found to be from either middle or high socio economic status. The demographic details, aphasia quotient on WAB, and proficiency ratings are given in Table 1.

Table 1.

*Demographic details, AQ of WAB, and proficiency level ratings of PWA (Group I).*

| Participant | Age/Gender | Site of lesion | Type of aphasia | WAB AQ | Proficiency rating in English (L2) – ISLPR (premorbid) | | | | Months post onset | Education |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | S | L | R | W | | |
| APH01 | 65/M | Left MCA CVA | Broca | 26 | 4 | 4 | 4 | 4 | 22 | BA |
| APH02 | 57/M | Left MCA CVA extending to Insula | Broca | 46.8 | 4 | 4 | 4 | 4 | 16 | B.Sc |
| APH03 | 35/M | Left MCA territory | Broca | 56.3 | 5 | 5 | 5 | 5 | 9 | B.E |
| APH04 | 46/M | Left subcortical CVA | Broca | 65.2 | 4 | 5 | 5 | 5 | 12 | BA |
| APH05 | 67/M | Left MCA/ACA CVA | Broca | 37.9 | 3 | 4 | 4 | 4 | 16 | M.Sc |
| APH06 | 62/M | Left MCA CVA | Broca | 62.3 | 4 | 4 | 4 | 4 | 20 | M.Sc |
| APH07 | 51/M | Acute left MCA/PCA territory infarct | Broca | 65.9 | 5 | 5 | 5 | 5 | 17 | B.Sc |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| APH08 | 72/M | Left fronto-temporal area infarct | Broca | 38.6 | 4 | 5 | 4 | 4 | 10 | B.Sc |
| APH09 | 56/M | Left MCA territory infarct | Broca | 49.3 | 4 | 4 | 4 | 4 | 15 | BE |
| APH10 | 45/M | Left MCA CVA | Broca | 54.8 | 5 | 5 | 5 | 5 | 10 | MA |
| APH11 | 62/M | Left MCA CVA | Broca | 69.3 | 4 | 4 | 4 | 4 | 22 | M.Sc |
| APH12 | 66/M | Left MCA CVA | Broca | 44.8 | 4 | 4 | 5 | 4 | 13 | B.Ed |
| APH13 | 53/M | Left frontoparietal infarct | Anomic | 75.5 | 4 | 5 | 4 | 4 | 9 | M.Com |
| APH14 | 37/M | Large CVA over left hemisphere | Broca | 29 | 5 | 5 | 5 | 4 | 7 | M.Sc |
| APH15 | 40/M | Left MCA infarct | Broca | 65.6 | 4 | 4 | 4 | 4 | 16 | B.Tech |
| APH16 | 56/M | Left MCA CVA (inferior division) | Broca | 66.7 | 5 | 5 | 5 | 5 | 22 | B.Sc |
| APH17 | 70/M | Left MCA infarct | Broca | 37.8 | 3 | 4 | 4 | 4 | 20 | B.Sc |
| APH18 | 58/M | Left fronto-temporal including insula | Broca | 40.3 | 4 | 4 | 4 | 4 | 15 | B.E |
| APH19 | 60/M | Left inferior frontal gyrus | Broca | 56.7 | 4 | 4 | 4 | 4 | 12 | B.Com |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | infarct | | | | | | | | |
| APH20 | 58/M | Left MCA CVA | Broca | 55.2 | 5 | 4 | 5 | 5 | 9 | M.A |

*Group II (typical group)* consisted of 20 age, gender, and proficiency matched typical bilingual (Kannada–English) participants. All the participants were right handed native speakers of Kannada and learned English as second language with 15 years of formal education. None of the participant had reported any history of auditory, visual, neurological/psychiatric illness, speech, language and cognitive deficits. All the participants were assessed for their proficiency in second language using ISLPR (Wylie & Inghram, 2006).

### 3.2. Materials

The following subjective tests were administered to assess the various language skills of both groups before undergoing ERP testing.

1. *Part–C (Kannada-English bilingualism) of Bilingual Aphasia Test - Kannada* (Paradis & Rangamani, 1989) was administered to both the groups to assess the language abilities in L1 and L2.

2. *Reading domain of Western Aphasia Battery in Kannada (Chengappa & Ravikumar, 2008) and in English (Kertesz, 1982)* were used to assess the reading comprehension of sentences in participants with aphasia.

3. *Language History Questionnaire* (Li, Sepansko, Zhao, 2006) was administered to assess the history of language acquisition and usage of both languages.

## 3.3. Development of stimuli

To assess semantic and syntactic processing in both groups using ERPs, sentences in three categories namely, correct sentences; semantically violated and syntactically violated sentences (details of number of stimuli are given in Table 2).

Table 2

*Sentence types and number of stimuli in each type.*

| Sl. No | Sentence Types | No. of Stimuli |
|---|---|---|
| 1 | Correct Sentences–Kannada | 50 |
| 2 | Semantically incorrect sentences-Kannada | 50 |
| 3 | Syntactically incorrect sentences-Kannada | 50 |
| 4 | Correct Sentences–English | 50 |
| 5 | Semantically incorrect sentences-English | 50 |
| 6 | Syntactically incorrect sentences-English | 50 |

A total of 100 sentences with MLU of 3–5 words under each type of sentence in Kannada and English were developed and were rated by two bilingual speech– language pathologists and two clinical linguists for similarities in syntactic complexity, concreteness/abstractness, imageability, on three-point rating scale. 50 sentences in each type in each language which were rated as similar in complexity, concreteness were considered for the experiment. Syntactic violations in the stimuli were formed by altering the tense structures, person-number-gender (PNG) markers, singular/plural errors and phrase structure violations (examples: the Indian team winned, & the washing machine wash). Semantic violations were formed by changing the semantic category, meaning of the sentence (examples: the tiger barked, the sleeves covered both moons) (Appendix-A & B).

### 3.4.Stimuli presentation

After taking the written informed consent from the participant or care giver, participants were assessed using the language proficiency measures and other subjective tests before conducting the ERP experiment. All the participants were instructed to wash their head thoroughly with shampoo and dry the hair to remove any oil content over the scalp before coming to the lab. Participants were seated comfortably in a chair in neurophysiology lab and the electrode cap was placed after placing the reference and ground electrodes on mastoid bones. Blunt needles were used to apply conduction gel across the 34 electrode locations to obtain the impedance below 5 kΩ. Once the impedance was below 5 kΩ at all the electrodes, the ERP experiment was started. The approximate time duration for the participant preparation was around 45 minutes.

All the three types of sentences (correct, syntactically violated, semantically violated) were presented randomly using GENTASK software of STIM2 hardware of Compumedics Neuroscan Inc, visually on a high resolution PC monitor, which were in black (font colour) on a white background with a resolution of 900*600 and were displayed in easily readable large–size (Times New Roman font for English and Baraha font for Kannada, 72 pt font size) letters. Each stimulus was displayed on centre of the screen for duration of 4000msec with an inter-stimulus interval time of 3000msec. The duration for stimuli presentation and inter-stimulus interval (ISI) were increased to 4000 ms and 3000 ms from the proposed 3000 ms and 2000 ms after a pilot study on five participants with aphasia. All the participants reported that a duration of 5000 ms (stimuli presentation and ISI) was significantly less for judging the sentence and responding. Hence, the stimuli duration and ISI were increased for the study.

In the semantic judgment task, participants were presented with 25 correct sentences and 50 semantically violated sentences randomly and they were instructed to read sentences silently and press the key-1 if the sentence was semantically correct and press the key-2 if the sentence was semantically violated on response pad. Similarly, in the grammaticality judgment task, the participants were presented with 25 correct sentences and 50 syntactically violated sentences randomly and they were instructed to read and press the key-1 if the sentence was syntactically correct and press the key-2 if the sentence was syntactically violated on response pad. The response pad had four keys in which key 1 and key 2 were placed on top and key 3 and key 4 were placed below. The participants were instructed to respond as accurately and as quickly as possible using either left or right hand. Reaction time and accuracy data were measured using *Compumedics Neuroscan Inc* system using STIM2 software. Initially the procedure was done in Kannada and later the same procedure was done in English (verbatim instructions are given in Appendix-C).

### 3.5.EEG Recording

Brain electrical activity was continuously recorded with a SynAmps2 amplifier of *Compumedics Neuroscan Inc* system from 34 Ag/Agcl electrodes placed according to the 10-20 international system (Figure 1). The 34 electrodes were selected after reviewing the previous research on language processing and the electrodes which were found to be useful in providing electrophysiological activity of language processing were used in the present study. A total of 34 electrodes were placed at different areas of scalp, frontal (F7, F3, Fz, F4, F8); temporal (T7, T8); parietal (P3, P5, Pz, P4, P6); occipital (O1, Oz, O2); central electrodes (C5, C3, Cz, C4, C6) and other electrodes are placed at frontal-temporal (FT7, FT8), front polar (FP1, FP2), frontal–central (FC3, FCz, FC4), temporo-parietal (TP7, TP8), centro-parietal (CP5, CP3, CPz, CP4, CP6), temporo-parietal (TP7, TP8) and two reference electrodes (M1, M2).

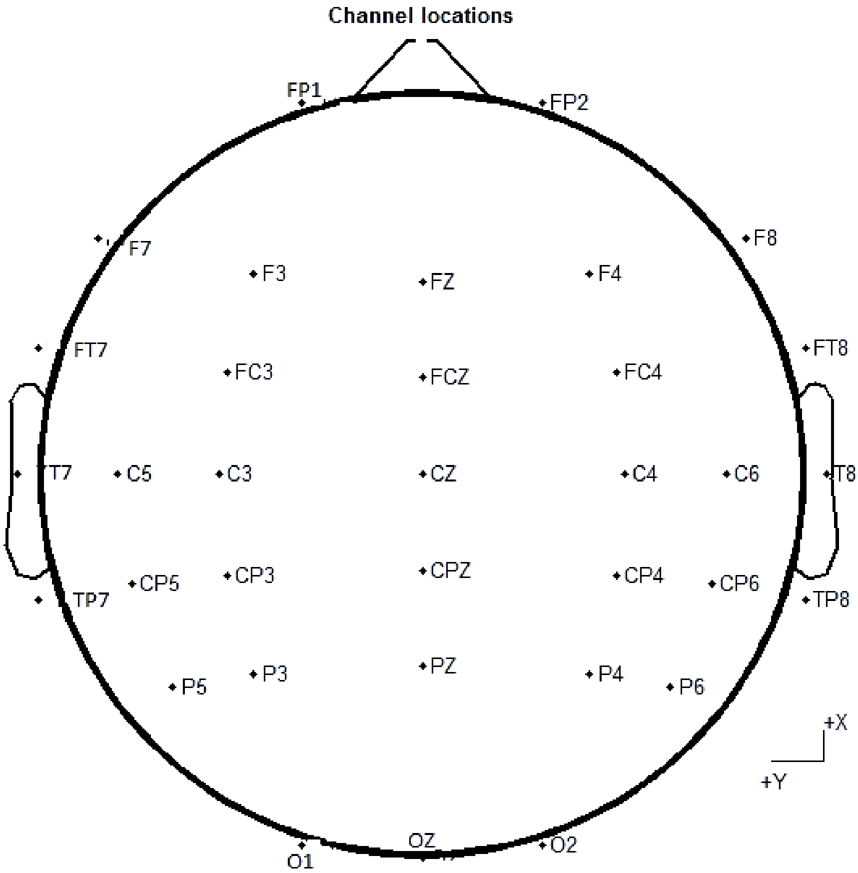


*Figure 1.* Montage of 34 electrodes on scalp used in EEG recording.

Before the data acquisition, the contact impedance between EEG electrodes and cortex was calibrated to less than 5 kΩ. The EEG recording parameters set in Neuroscan system were given in Table 3. It was ensured that both subjective (caused by eye movements, and other physical movements) and instrumental artifacts were eliminated during the recording of responses.

Table 3.

*EEG recording parameters set in Neuroscan system.*

| **EEG parameters** | **Settings** |
|---|---|
| Sampling frequency | 1000/second |
| Electrode placement | 34 electrode (10-20 international system) |
| Impedance | < 5 kΩ |
| Amplification | 20,000 (set in SynAmps system) |
| Time window | 1200 msec (-200msec pre to 1000msec post stimulus) |
| Inter Trial Interval | 7000 msec (stimulus duration of 4000msec + Inter stimulus interval of 3000msec) |
| No. of averages | 50–correct sentences ; 50–syntactically violated sentences; 50–semantically incorrect sentences in each language. |
| Artifact rejection level | ± 100 µv. |

**3.6.EEG Data analysis**

All the EEG recordings were digitally high pass filtered at 4 Hz (filter slope – 12dB/octave) to visualize the various components of ERPs. The recorded EEG files were analyzed offline using independent component analysis of MATLAB version 2009b to eliminate artifacts caused by eye movements. The responses were analyzed for N400 and P600 components in the time window of 300-500 ms and 500-700 ms respectively for each electrode. The mean amplitudes of each time window were measured for each electrode for both correct and violated conditions. Statistical analysis was done to measure the differences in amplitude levels at each electrode. All the electrodes were divided into three hemispheric regions namely left hemisphere, right hemisphere and central locations. Further, these electrodes were divided into eight regions of interest (ROI) namely, left anterior (FP1, F3, F7, FC3, FT7), right anterior (FP2, F4, F8, FC4, FT8), left central (C5, C3), right central (C6, C4), left centro-parietal (CP5, CP3), right centro-parietal (CP4, CP6), left posterior (P5, P3) and right posterior (P4, P6) to understand the topographical organization of language processing.

### 3.7.Research Design

Standard group comparison was used in the present study. The performance in L1 and L2 of group I and group II were compared within and across groups. Type of sentences and language were independent variables and accuracy, reaction time data, N400, and P600 were dependent variables.

### 3.8.Statistical Analysis

Parametric tests such as independent samples test, ANOVA, and repeated measures ANOVA were used to analyse the results of behavioral measures. For analysis of electrophyiological measures, non-parametric tests such as mann-whitney U test for comparison of two groups, Friedman test was used for comparing the differences between electrodes, scalp regions and hemispheres in both the languages for both the groups and for post-hoc analysis, wilcoxon test was used. 2-related samples test was used for comparing between types of sentences and for comparing between Kannada and English in each group.

# Chapter 4

# RESULTS AND DISCUSSION

The aim of the present study was to explore the neurophysiological differences in language processing in Kannada and English in bilingual individuals with aphasia and typical bilingual individuals. A total of 20 subjects participated in each of the clinical and typical group. All the participants were assessed using Part-C of Bilingual Aphasia test (Kannada-English) and Reading comprehension domain of Western Aphasia Battery in Kannada and English. Further, all the subjects participated in both semantic and syntactic judgment tasks, during which behavioural (accuracy and reaction time) and electrophysiological measurements (N400 and P600) were recorded. The results of the present study are given in two sections, behavioral and electrophysiological measures.

## 4.1. Performance of Group I and Group II on Behavioural Measures

The present study included some of the behavioural measures along with electrophysiological measures. As part of behavioural measures, both the groups were assessed using part-c of BAT (Kannada-English bilingualism), reading comprehension scores of WAB in Kannada and English, accuracy and reaction time measures of semantic and syntactic judgment tasks.

### *4.1.1. Performance of group I and group II on Part-C of Bilingual Aphasia test (Kannada-English).*

Part–C (Kannada-English bilingualism) of Bilingual Aphasia Test - Kannada (Paradis & Rangamani, 1989) was used to assess the language abilities of participants in group I and II in Kannada and English. The mean and standard deviation (SD) values of each group were computed and are given in Table 4. As shown in Table 4, the performance of group I is poor than that of group II on all the tasks.

Table 4.

*Mean, SD, and results of independent samples t-test for group I and II.*

| Task | Group | M | SD | *t* | *df* | *p-value* |
|---|---|---|---|---|---|---|
| Word Recognition (Kannada-English) | Group I | 2.95 | .68 | 13.358 | 38 | 0.00** |
| | Group II | 5.0 | 0.00 | | | |
| Word Recognition (English-Kannada) | Group I | 3.10 | .64 | 13.262 | 38 | 0.00** |
| | Group II | 5.0 | 0.0 | | | |
| Word translation (Kannada-English) | Group I | 4.30 | 0.98 | 26.045 | 38 | 0.00** |
| | Group II | 10 | 0.0 | | | |
| Word translation (English-Kannada) | Group I | 4.05 | 1.14 | 23.221 | 38 | 0.00** |
| | Group II | 10 | 0.0 | | | |
| Translation of sentences (Kannada-English) | Group I | 7.40 | 1.46 | 27.159 | 38 | 0.00** |
| | Group II | 17.60 | 0.82 | | | |
| Translation of sentences (English-Kannada) | Group I | 9.55 | 1.27 | 23.537 | 38 | 0.00** |
| | Group II | 17.55 | 0.82 | | | |
| Grammaticality judgment in Kannada | Group I | 5.70 | 0.86 | 11.898 | 38 | 0.00** |
| | Group II | 8.00 | 0.0 | | | |
| Grammaticality judgment in English | Group I | 5.15 | 0.87 | 13.258 | 38 | 0.00** |
| | Group II | 7.90 | 0.31 | | | |

**$p<0.01$.

*Note.* M = Mean. SD = Standard Deviation.

Results of independent samples t-test showed significant differences between the two groups on all the tasks and the results are given in Table 4. Results of subtests of Part-C of BAT test indicated that bilingual individuals with aphasia have impairments in both L1 and L2. Graphical representation of performance of two groups is depicted in Figure 2.

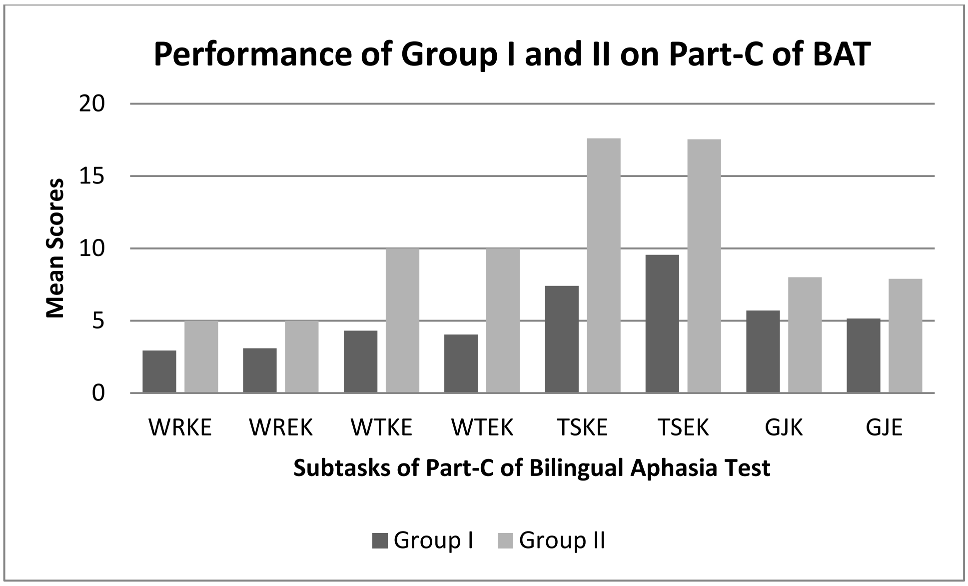


*Figure 2.* Performance of group I and II on various tasks of Part-C of BAT. `

*Note.* WRKE: Word Recognition (Kannada-English); WREK: Word Recognition (English-Kannada); WTKE: Word Translation (Kannada-English); WTEK: Word Translation (English-Kannada); TSKE: Translation of sentences from Kannada to English; TSEK: Translation of sentences from English to Kannada; GJK: Grammaticality judgment of Kannada sentences; GJE: Grammaticality judgment of English sentences.

#### *4.1.2. Performance of group I and II on reading comprehension domain of Western Aphasia Battery in Kannada and English.*

Reading comprehension abilities of group I and II were assessed by using Western Aphasia Battery in Kannada and English. The mean and standard deviations (SD) were computed and given in Table 5.

Table 5.

*Mean and SD values of group I and II on reading comprehension subtest and results of independent samples test.*

| **Language** | **Group** | **M** | **SD** | ***t*** | ***df*** | ***p-value*** |
|---|---|---|---|---|---|---|
| Kannada | Group I | 28.90 | 3.21 | 15.46 | 38 | 0.00** |
| | Group II | 40.00 | 0.00 | | | |
| English | Group I | 27.30 | 3.39 | 16.76 | 38 | 0.00** |
| | Group II | 40.00 | 0.00 | | | |

**$p$<0.01. *Note.* M = Mean. SD = Standard Deviation.

As shown in Table 5, the performance of group I was poorer than that of group II. Independent samples t-test revealed significant differences between the two groups in both languages. Graphical representation of the performance of two groups is given in Figure 3.

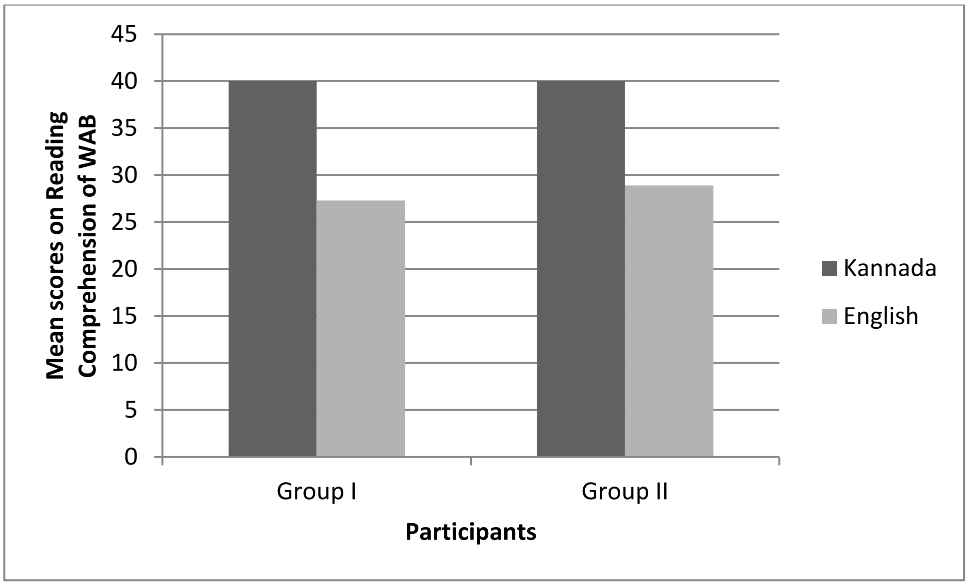


*Figure 3*. Performance of group I and II on reading comprehension task in Kannada and English.

***4.1.3. Performance of clinical and typical groups on accuracy measures for three types of sentences in Kannada and English.***

Analysis of accuracy scores in group I and II revealed significant decrease in mean scores of group I in both Kannada and English languages for all the three types of sentences. Table 6 presents the mean accuracy data as a function of participant group, language and type of sentences.

Table 6.

*Mean scores of accurate responses for three types of sentences across L1 and L2 in group I and II.*

| **Type of sentences** | **Language** | **Group I** | | **Group II** | |
|---|---|---|---|---|---|
| | | **Mean** | **S.D.** | **Mean** | **S.D.** |
| Correct sentences | Kannada | 34.7 | 6.90 | 46.7 | 1.59 |
| | English | 31.95 | 7.60 | 44.7 | 2.386 |
| Semantically incorrect sentences | Kannada | 31.6 | 5.12 | 44.5 | 2.625 |
| | English | 30.6 | 7.62 | 43.15 | 3.91 |
| Syntactically incorrect sentences | Kannada | 23.55 | 5.81 | 41.9 | 2.731 |
| | English | 18.1 | 4.98 | 37.15 | 7.11 |

Results of MANOVA revealed significant effect of participant groups for correct sentences [$F (1, 38) = 108.485$, $p < 0.05$], semantically violated sentences [$F (1, 38) = 139.347$, $p < 0.05$], syntactically violated sentences [$F (1, 38) = 305.563$, $p < 0.05$] in Kannada, correct sentences [$F (1, 38) = 173.937$, $p < 0.05$], semantically violated sentences [$F (1, 38) = 117.505$, $p < 0.05$], syntactically violated sentences [$F (1, 38) = 143.031$, $p < 0.05$] in English languages.

Mixed ANOVA analysis revealed significant interaction effect between types of sentences*participant groups [$F (2, 76) = 22.652$, $p < 0.05$] and types of sentences*language [$F (2, 76) = 9.062$, $p < 0.05$]. However, no significant interaction effects were found between language*participant group [$F (1, 38) = 0.293$, $p> 0.05$]. Further, mixed ANOVA analysis also revealed significant interaction effect between language*type of sentences*subject groups [$F (2, 76) = 0.314$, $p < 0.05$]. Figure 4 depicts the graphical representation of mean performance levels of group I and II for each type of sentence in Kannada and English.

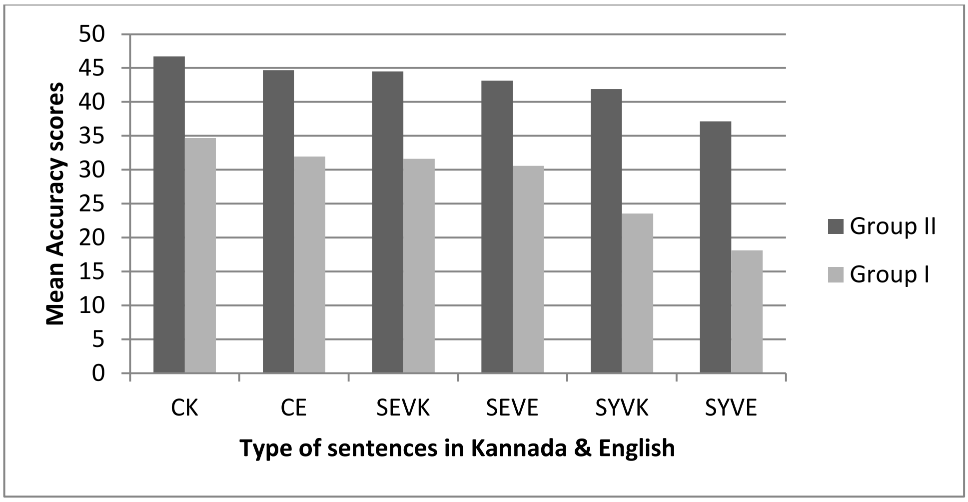


*Figure 4.* Mean accuracy scores of group I and II in Kannada and English.

*Note.* CK: Correct sentences in Kannada; CE: Correct sentences in English; SEVK: Semantically violated sentences in Kannada; SEVE: Semantically violated sentences in English; SYVK: Syntactically violated sentences in Kannada; SYVE: Syntactically violated sentences in English.

Repeated measures ANOVA results indicated that there was a main effect of type of sentence in accuracy data of three types of sentences in Kannada for group I [F (2, 38) = 84.920, p < 0.05] and for group II [F (2, 38) = 30.527, p < 0.05]. In group I, pair-wise comparisons revealed significant differences between accuracy scores of correct and semantically violated sentences ($p$<0.05) and also between correct sentences and syntactically violated sentences ($p$<0.05) on accuracy measures indicating a significant effect of semantic and syntactic violations in Kannada. Similarly, in group II, pair-wise comparison revealed significant differences between judgment of correct and semantically violated sentences ($p$<0.05) and also between correct sentences and syntactically violated sentences ($p$<0.05) on accuracy measures, indicating a significant effect of semantic and syntactic violations in Kannada.

Repeated measures ANOVA results indicated that there was a main effect of type of sentence in accuracy data of three types of sentences in English as well for group I [F (2, 38) = 161.340, p < 0.05] and for group II [F (2, 38) = 13.865, p < 0.05]. In group I, pair-wise comparisons revealed no significant difference between accuracy scores of correct and syntactically violated sentences ($p$ > 0.05). On the other hand, pair-wise comparisons revealed a significant difference between correct sentences and semantically violated sentences ($p$ < 0.05) on accuracy measures in L2. In group II, however, pair-wise comparisons revealed no significant difference between accuracy scores of correct and semantically violated sentences ($p > 0.05$). In contrast, pair-wise comparisons did reveal a significant difference between correct sentences and syntactically violated sentences ($p < 0.05$) on accuracy measures in English.

In group I, paired samples t-test results revealed a significant difference in performance between Kannada and English for correct sentences [t (19) = 3.955, p < 0.05] and syntactically violated sentences [t (19) = 5.687, p < 0.05]. However, no significant difference was found between Kannada and English languages for semantically violated sentences [t (19) = 1.209, p > 0.05]. In group II, paired t-test results revealed a significant difference in performance between Kannada and English for correct sentences [t (19) = 2.973, p < 0.05] and syntactically violated sentences [t (19) = 2.991, p < 0.05]. However, no significant difference was found between Kannada and English languages for semantically violated sentences [t (19) = 1.549, p > 0.05].

***4.1.4. Performance of group I and II on reaction time measures for three types of sentences in Kannada and English.***

Analysis of reaction times in group I and II revealed significant delay in mean scores of group I in both Kannada and English languages for all the three types of sentences. Table 7 presents the mean reaction times in milliseconds (ms) as a function of participant group, language and type of sentences.

Table 7.

*Mean reaction time in milliseconds (ms) for three types of sentences across L1 and L2 in group I and II.*

| **Type of sentences** | **Language** | **Group I** | | **Group II** | |
|---|---|---|---|---|---|
| | | **Mean RT in ms.** | **S.D.** | **Mean RT in ms.** | **S.D.** |
| Correct sentences | Kannada | 8960.60 | 1990.21 | 3002.52 | 664 |
| | English | 12456.37 | 2312.95 | 2150.67 | 399.62 |
| Semantically violated sentences | Kannada | 12697.95 | 3034.80 | 2792.01 | 642.03 |
| | English | 14710.17 | 2469.08 | 1928.04 | 410.12 |
| Syntactically violated sentences | Kannada | 15505.98 | 2343.27 | 2766.02 | 703.73 |
| | English | 2625.75 | 495.92 | 16469.12 | 2692.28 |

Results of MANOVA revealed significant effect of participant groups for correct sentences [F (1, 38) = 161.262, p < 0.05], semantically violated sentences [F (1, 38) = 203.96, p < 0.05], syntactically violated sentences [F (1, 38) = 542.271, p < 0.05] in Kannada, correct sentences [F (1, 38) = 385.546, p < 0.05], semantically violated sentences [F (1, 38) = 521.608, p < 0.05], syntactically violated sentences [F (1, 38) = 511.423, p < 0.05] in English language.

Mixed ANOVA analysis revealed significant interaction effect between types of sentences*participant groups [F (2, 76) = 60.466, p < 0.05] and language*participant groups [F (1, 38) = 38.722, p < 0.05]. However, no significant interaction effects were found between language*type of sentences [F (2, 76) = 2.994, p > 0.05]. Further, mixed ANOVA analysis also revealed significant interaction effect between language*type of sentences*participant groups [F (2, 76) = 8.377, p < 0.05]. Figure 5 depicts the graphical representation of mean performance levels of typical and clinical groups for each type of sentence in Kannada and English.

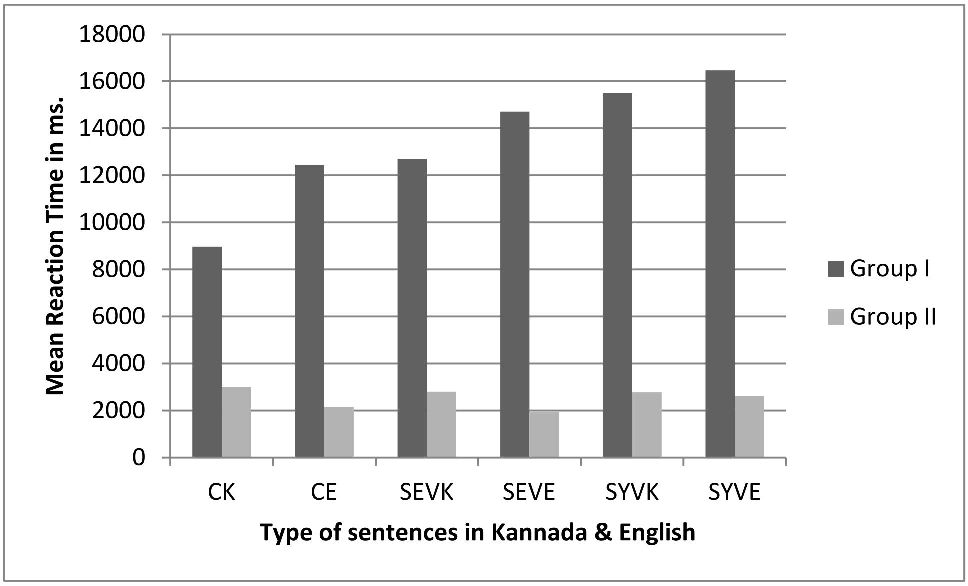


*Figure 5.* Mean reaction times (in ms) of typical and clinical groups in Kannada and English.

*Note.* CK: Correct sentences in Kannada; CE: Correct sentences in English; SEVK: Semantically violated sentences in Kannada; SEVE: Semantically violated sentences in English; SYVK: Syntactically violated sentences in Kannada; SYVE: Syntactically violated sentences in English.

Repeated measures ANOVA results indicated that there was no main effect of type of sentence in reaction time data of three types of sentences in Kannada for typical group

[F (2, 38) = 0.604, p > 0.05] and significant main effect of type of sentence in reaction time data of three types of sentences in Kannada for clinical group [F (2, 38) = 65.654, p < 0.05]. In typical group, pair-wise comparison revealed no significant differences between judgment of correct and semantically violated sentences (*p* > 0.05) and also between correct sentences and syntactically violated sentences (*p* > 0.05) on reaction time measures, indicating no significant effect of semantic and syntactic violations in Kannada on reaction times. Pair-wise comparisons in clinical group revealed significant differences between accuracy scores of correct and semantically violated sentences (*p* < 0.05) and also between correct sentences and syntactically violated sentences (*p* < 0.05) on accuracy measures indicating a significant effect of semantic and syntactic violations in Kannada.

Repeated measures ANOVA test results indicated that there was a main effect of type of sentence in reaction time data of three types of sentences in English for typical group [F (2, 38) = 10.960, p < 0.05] and for clinical group [F (2, 38) = 22.483, p < 0.05]. In typical group, however, pair-wise comparisons revealed no significant difference between reaction times of correct and semantically violated sentences (*p* > 0.05). In contrast, pair-wise comparisons did reveal a significant difference between correct sentences and syntactically violated sentences (*p* < 0.05) on reaction time measures in English. In clinical group, pair-wise comparisons revealed significant difference between reaction time measures of correct and syntactically violated sentences (*p* < 0.05) and between correct and semantically violated sentences (*p* < 0.05). On the other hand, pair-wise comparisons revealed no significant difference between semantically violated sentences and syntactically violated sentences (*p* > 0.05) on reaction time measures in English.

In typical group, paired t-test results revealed a significant difference in reaction times between Kannada and English for correct sentences [t (19) = 5.430, p < 0.05] and semantically violated sentences [t (19) = 4.913, p < 0.05]. However, no significant difference was found between Kannada and English languages for syntactically violated sentences [t (19) = 0.679, p > 0.05]. In clinical group, paired samples t-test results revealed a significant difference in reaction times between Kannada and English for correct sentences [t (19) = 8.178, p < 0.05] and semantically violated sentences [t (19) = 2.648, p < 0.05]. However, no significant difference was found between Kannada and English languages for syntactically violated sentences [t (19) = 1.586, p > 0.05].

## 4.2. Electrophysiological Measures

A total of 34 electrodes were used to record event related potentials from participants of typical and clinical groups during semantic and syntactic processing in Kannada and English. The results of electrophysiological measures were analyzed in three ways, namely, electrode-wise, scalp region-wise, and hemispheric-wise in two languages in two groups. Under electrode-wise analysis, responses at each of the 34 electrodes were analyzed in all conditions and compared with that of other electrodes. Under scalp region-wise analysis, eight regions of scalp, left anterior (FP1, F3, F7, FC3, FT7), right anterior (FP2, F4, F8, FC4, FT8), left central (C5, C3), right central (C4, C6), left centro-parietal (CP5, CP3), right centro-parietal (CP6, CP4), left posterior (P5, P3), and right posterior (P4, P6) were selected and were compared to investigate the area wise differences in activation during processing of semantic and syntactic structures. In hemispheric-wise analysis, all 34 electrodes were divided into left, right and central areas and further analysis were carried out to investigate the differences in hemispheric activation.

**Objective 1: To study whether the same cortical regions mediate two languages in individuals with bilingual aphasia.**

### 4.2.1. *Electrode-wise analysis of N400 effect in group I in Kannada and English.*

The ERP responses of all 34 electrodes were analyzed and the mean values of responses in the duration of 300-500ms were extracted by using independent component analysis of Matlab software for measuring N400 effect in group I. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of 34 electrodes for semantically correct and semantically incorrect sentences in Kannada for group I. Table 8 and 9 represent the mean, median and standard deviations and /Z/ values of N400 component for clinical groups for correct sentences and semantically incorrect sentences in Kannada and English respectively.

Table 8.

*Mean, Median and SD values of amplitude of N400 components for group I for semantically correct and semantically incorrect sentences in Kannada.*

| Electrode | Amplitudes for Semantically correct sentences | | | Amplitudes for Semantically incorrect sentences | | | /Z/ |
|---|---|---|---|---|---|---|---|
| | Mean (in µv) | Median | SD (in µv) | Mean (in µv) | Median | SD (in µv) | |
| O2 | -.185 | -.119 | .817 | -.042 | -.144 | .777 | -.112 |
| O1 | -.437 | -.153 | .963 | -.172 | -.286 | .992 | -.747 |
| Oz | -.433 | -.264 | .804 | -.222 | -.418 | .928 | -.336 |
| Pz | -.089 | .014 | .844 | -.005 | -.302 | .837 | -.261 |
| P4 | -.097 | .070 | 1.093 | .174 | .101 | .690 | -1.045 |
| P6 | -.115 | -.055 | .895 | .076 | .029 | .580 | -.485 |
| P5 | -.291 | -.160 | .948 | -.182 | -.245 | 1.010 | -.299 |
| P3 | -.022 | -.003 | .797 | -.054 | -.260 | .915 | -.597 |
| Cz | -.101 | .078 | 1.039 | -.125 | -.132 | .846 | -.560 |
| C3 | -.076 | .294 | 1.190 | -.038 | -.199 | .870 | -.299 |
| C5 | .272 | .458 | 1.100 | -.292 | -.171 | .970 | -2.053* |
| C4 | .084 | .199 | .836 | .155 | .101 | .674 | -.037 |
| C6 | .248 | .368 | .864 | .104 | .094 | .695 | -.672 |
| T7 | .064 | .436 | 1.448 | -.081 | -.166 | .910 | -.299 |
| T8 | .229 | .297 | .878 | .202 | -.065 | .977 | -.560 |
| Fz | .191 | .398 | 1.241 | .178 | .334 | .932 | -.261 |
| F3 | .193 | .462 | 1.160 | .329 | .551 | 1.09 | -.560 |
| F7 | .124 | .034 | 1.492 | .453 | .100 | 1.023 | -1.344 |
| F4 | .551 | .509 | .897 | .33 | .535 | .783 | -1.045 |
| F8 | .673 | .579 | 1.056 | .351 | .403 | .689 | -.971 |
| FT8 | .658 | .476 | 1.078 | .57 | .557 | .740 | -.325 |
| FT7 | .229 | .574 | 1.485 | -.003 | -.094 | .914 | -.896 |
| FP1 | .878 | .662 | 1.469 | .154 | .176 | .867 | -2.240* |
| FP2 | .711 | .693 | 1.460 | .424 | .197 | .776 | -1.344 |
| FC3 | .042 | .383 | 1.119 | .100 | .123 | .979 | -.149 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| FC4 | .238 | .394 | 1.037 | .230 | .432 | .735 | -.261 |
| FCz | .019 | .178 | .902 | -.027 | -.152 | .981 | -.224 |
| CP5 | -.082 | -.007 | 1.235 | -.216 | -.23 | .941 | -.635 |
| TP7 | .158 | -.039 | 1.458 | -.302 | -.133 | 1.035 | -1.680 |
| TP8 | .026 | .072 | .500 | .017 | .03 | .422 | -.299 |
| CPz | -.054 | .058 | .781 | -.011 | -.141 | .711 | -.187 |
| CP4 | -.004 | .195 | .973 | .007 | -.002 | .691 | -.336 |
| CP6 | .194 | .099 | .735 | .093 | .108 | .584 | -.373 |
| CP3 | -.172 | .079 | 1.095 | -.069 | -.155 | .850 | -.224 |

Note: *: p<0.05; **: p<0.01.

In L1, N400 component (reduced shift in amplitudes) for semantically incorrect sentences was observed at O1, Oz, Pz, P5, P3, Cz, C3, C5, C6, T7, T8, FT7, FP1, FP2, FC3, FCz, CP5, TP7, CPz, CP4, and CP3 indicating that the distribution of N400 is mainly distributed over left hemisphere and few sites of right hemisphere. However, significant differences between semantically correct and semantically incorrect sentences were found at the central and fronto-parietal electrodes sites of left hemisphere.

Table 9.

*Mean, Median and SD values of amplitude of N400 components for group I for semantically correct and semantically incorrect sentences in English.*

| **Electrode** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in μv)** | **Median** | **SD (in μv)** | **Mean (in μv)** | **Median** | **SD (in μv)** | |
| O2 | .534 | .585 | .941 | -.429 | -.48 | .687 | -3.24** |
| O1 | .232 | .38 | .984 | -1.12 | -1.09 | .933 | -3.43** |
| Oz | .049 | .12 | .856 | -1.00 | -1.17 | .769 | -.324** |
| Pz | .493 | .575 | .919 | -.32 | -.30 | 1.032 | -2.83** |
| P4 | .781 | .872 | .822 | .27 | .39 | 1.036 | -1.941 |
| P6 | .706 | .76 | .78 | .31 | .49 | .924 | -1.904 |
| P5 | .383 | .64 | 1.26 | -1.23 | -1.182 | .934 | -3.69** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| P3 | .64 | .792 | 1.179 | -.675 | -.49 | 1.08 | -3.54** |
| Cz | .60 | .491 | .842 | -.12 | -.042 | .82 | -2.61** |
| C3 | .66 | .68 | .94 | -.36 | -.431 | .876 | -3.21** |
| C5 | .55 | .84 | 1.08 | -.786 | -.773 | .792 | -3.80** |
| C4 | .87 | 1.02 | .813 | .497 | .72 | 1.028 | -1.269 |
| C6 | 1.08 | 1.19 | .731 | .55 | .674 | 1.11 | -1.829 |
| T7 | .414 | .519 | 1.16 | -1.22 | -1.27 | .940 | -3.77** |
| T8 | .556 | .706 | .573 | .63 | .763 | 1.136 | -.896 |
| Fz | .60 | .72 | .748 | .009 | .076 | .780 | -2.65** |
| F3 | .74 | .71 | .573 | -.181 | -.183 | 1.029 | -3.32** |
| F7 | .037 | .009 | .544 | -.14 | -.001 | 1.028 | -.075 |
| F4 | .886 | .823 | .706 | .27 | .413 | .851 | -2.50** |
| F8 | .92 | .99 | .574 | .804 | .99 | 1.04 | -.187 |
| FT8 | .853 | .884 | .496 | .737 | .801 | .908 | -.336 |
| FT7 | .24 | .48 | 1.129 | -.72 | -.54 | .994 | -2.61** |
| FP1 | .872 | .95 | .734 | .15 | .06 | 1.37 | -2.50** |
| FP2 | .786 | .793 | .815 | .205 | .310 | 1.12 | -1.867 |
| FC3 | .60 | .62 | .842 | -.37 | -.34 | .784 | -3.62** |
| FC4 | 1.00 | .86 | .864 | .345 | .498 | .89 | -2.20* |
| FCz | .654 | .648 | .854 | -.01 | .001 | .691 | -2.68* |
| CP5 | .55 | 1.04 | 1.12 | -1.04 | -.98 | .856 | -3.80** |
| TP7 | .28 | .59 | 1.59 | -1.61 | -1.52 | .943 | -3.92** |
| TP8 | .72 | .86 | .761 | .49 | .56 | 1.00 | -.709 |
| CPz | .764 | .78 | .913 | -.11 | -.08 | .907 | -2.72** |
| CP4 | .85 | 1.0 | .86 | .49 | .72 | 1.03 | -1.23 |
| CP6 | .90 | 1.05 | .847 | .66 | .85 | 1.043 | -.821 |
| CP3 | .62 | .81 | 1.04 | -.449 | -.288 | .940 | -3.32** |

Note: *: $p<0.05$; **: $p<0.01$.

In L2, N400 component for semantically incorrect sentences was observed at O2, 01, Oz, Pz, P4, P6, P5, P3, Cz, C3, C5, C6, T7, Fz, F3, F4, FT7, FP1, FP2, FC3, FCz, CP5, TP7, CPz, and CP3. The N400 effect in clinical group was broadly distributed in both right and left hemispheres. However, significant differences between amplitudes of semantically correct and semantically incorrect sentences were observed at bilateral occipital, left parietal, central, fronto-central, and centro-parietal regions. These results indicated bilateral hemispheric activation for both L1 and L2 in bilingual individuals although the activation levels are higher in L2 than L1 in right hemisphere. Figure 6 and 7 represent the grand average waveforms of N400 components of group I in Kannada and English respectively.

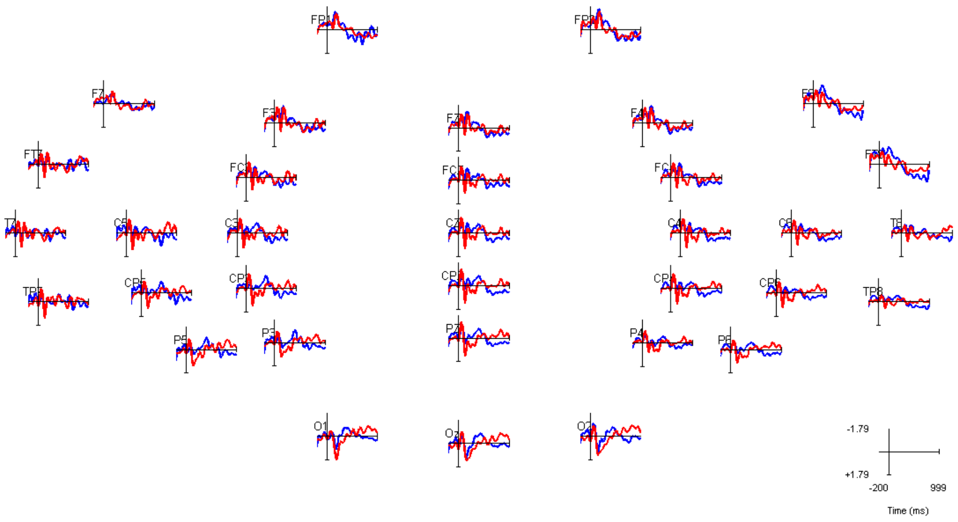


*Figure 6*. Grand average waveforms of 34 electrodes of Group I for semantically correct and semantically incorrect sentences in Kannada.

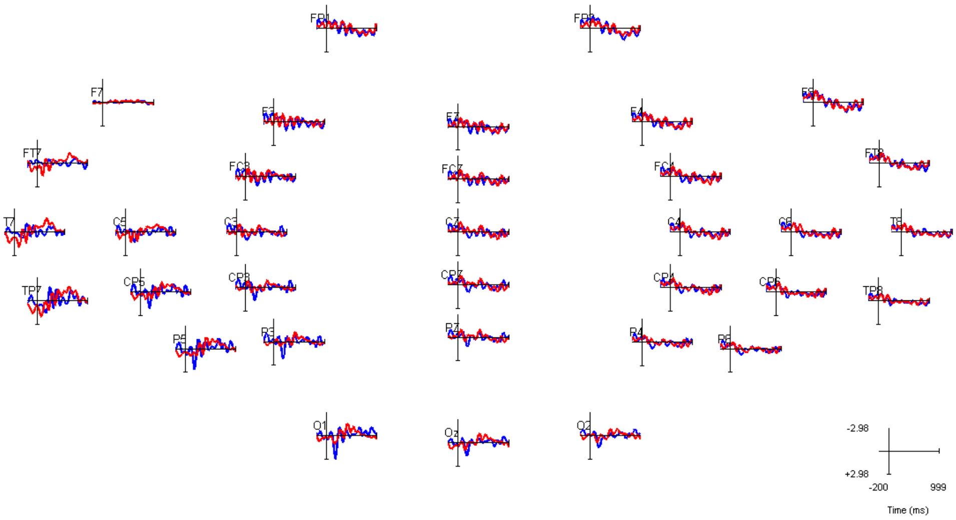


*Figure 7*. Grand average waveforms of 34 electrodes of Group I for semantically correct and semantically incorrect sentences in English.

*4.2.1.1. Between electrode comparison for 34 electrodes for Group I of semantically correct and semantically incorrect sentences in Kannada.*

Friedman test results revealed significant difference between the 34 electrodes for group I ($\chi^2$ (33) = 113.66, $p < .01$). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group I for each type of sentence. Results of pair-wise comparisons between electrodes for group I for correct sentences in Kannada are given in Table 10.

Table 10.

*Pair-wise comparisons of 34 electrodes for correct sentences in Kannada for group I.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | + | + | - | - | - | - | - | - | - | - | + | + | - | - | + | - | - | + | + | + | - | + | + | - | + | - | - | - | - | - | - | + | - |
| O1 | | | - | + | - | - | - | + | - | + | + | + | + | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | - | + | + | + | + | + |
| Oz | | | | + | + | + | - | + | + | - | + | + | + | - | + | + | + | - | + | + | + | + | + | + | + | + | + | - | - | + | + | + | + | - |
| Pz | | | | | - | - | - | - | - | - | - | + | + | - | - | + | - | - | + | + | + | - | + | + | - | + | - | - | - | - | - | - | - | - |
| P4 | | | | | | - | - | - | - | - | - | - | + | - | - | - | - | - | - | + | + | - | + | + | - | - | - | - | - | - | - | - | + | - |
| P6 | | | | | | | - | - | - | - | - | - | + | - | - | - | - | - | + | + | + | - | + | + | - | - | - | - | - | - | - | - | + | - |
| P5 | | | | | | | | + | - | - | + | + | - | + | + | - | - | + | + | + | + | - | + | + | + | + | + | + | - | - | - | + | + | - |
| P3 | | | | | | | | | - | - | - | - | + | - | - | - | - | - | + | + | + | - | + | - | - | + | - | - | - | - | - | - | - | - |
| Cz | | | | | | | | | | - | - | - | - | - | - | + | - | - | + | + | + | - | + | + | - | + | - | - | - | - | - | - | - | - |
| C3 | | | | | | | | | | | - | - | - | - | - | - | - | - | + | - | - | - | + | - | - | + | - | - | - | - | - | - | - | - |
| C5 | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - |
| C4 | | | | | | | | | | | | | - | - | - | - | - | - | + | + | - | - | + | + | - | - | - | - | - | - | + | - | - | + |
| C6 | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | + |
| T7 | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | - | - | - | - | - | + | - | - | + | - | - | - | - | - | - | - | - | - | - |
| Fz | | | | | | | | | | | | | | | | | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - |
| F3 | | | | | | | | | | | | | | | | | | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - |
| F4 | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | + | - | + | - | - | + | + | + | - | + |
| F8 | | | | | | | | | | | | | | | | | | | | | + | - | - | - | - | - | + | - | - | + | + | + | - | + |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FT8 | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | + | + | + | - | + |
| FT7 | | | | | | | | | | | | | | | | | | | | | | + | - | - | - | - | - | - | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | - | + | - | + | + | - | + | + | + | - | + |
| FP2 | | | | | | | | | | | | | | | | | | | | | | | | - | + | + | - | - | + | + | + | - | + |
| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | - | - | + | - | + |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: ‘+’: p<0.001; ‘-‘: p>0.001.

Friedman test results revealed significant difference between the electrodes for Group I for semantically incorrect sentences ($\chi^2$ (33) = 94.275, $p$ < .01). Wilcoxon post hoc tests results of pair-wise comparisons between electrodes for group I for semantically incorrect sentences in Kannada are given in Table 11.

Table 11.

*Pair-wise comparisons of 34 electrodes for semantically incorrect sentences in Kannada for group I.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - |
| O1 | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oz | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Pz | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P4 | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P6 | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P5 | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P3 | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cz | | | | | | | | | | - | - | + | - | - | - | - | - | - | + | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - |
| C3 | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C5 | | | | | | | | | | | | - | - | - | - | - | + | - | + | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - |
| C4 | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C6 | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T7 | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Fz | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - |
| F3 | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F4 | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - |
| F8 | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | + | - | - | - | - | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | + | - | - | - | - | - |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - |
| FP | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | + | - | - | - | - | - |

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| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: p<0.001; -: p>0.001.

*4.2.1.2. Between electrode comparison for 34 electrodes for Group I of semantically correct and semantically incorrect sentences in English.*

Friedman test results revealed significant difference between the electrodes for group I ($\chi^2$ (33) = 99.607, $p$ < .01) in English for semantically incorrect sentences. Wilcoxon post-hoc test results of pair-wise comparisons between electrodes for group I for correct sentences in English are given in Table 12.

Table 12.

*Pair-wise comparisons of 34 electrodes for semantically correct sentences in English for group I.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | - | + | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| O1 | | | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | + | - | + | - |
| Oz | | | | - | + | + | - | - | - | - | - | + | + | - | - | - | - | - | + | + | + | - | - | - | - | + | - | - | - | + | + | + | + | - |
| Pz | | | | | + | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | + | + | + | - |
| P4 | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P6 | | | | | | | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P5 | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P3 | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cz | | | | | | | | | | - | - | + | + | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - |
| C3 | | | | | | | | | | | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - |
| C5 | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C4 | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C6 | | | | | | | | | | | | | | - | + | + | - | + | - | - | - | + | - | - | + | - | - | - | - | + | - | - | - | + |
| T7 | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Fz | | | | | | | | | | | | | | | | | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F3 | | | | | | | | | | | | | | | | | | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F7 | | | | | | | | | | | | | | | | | | | + | + | + | - | + | + | - | + | - | - | - | + | - | - | + | - |
| F4 | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F8 | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - |
| FP | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - |

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| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | - | - | - | - | - | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | - | - | - | - | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: $p<0.001$; -: $p>0.001$.

Friedman test results revealed significant difference between the electrodes for Group I for semantically incorrect sentences in English ($\chi^2$ (33) = 364.969, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group I for semantically incorrect sentences. Results of pair-wise comparisons between electrodes for group I for semantically incorrect sentences in English are given in Table 13.

Table 13.

*Pair-wise comparisons of 34 electrodes for semantically incorrect sentences in English for clinical group.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | + | + | - | + | + | + | - | - | - | - | + | + | + | + | - | - | - | + | + | + | - | - | - | - | + | - | + | + | + | - | + | + | - |
| O1 | | | - | - | + | + | - | - | + | + | - | + | + | - | + | + | - | - | + | + | + | - | - | + | + | + | + | - | - | + | + | + | + | + |
| Oz | | | | + | + | - | - | + | + | - | + | + | - | + | + | - | + | + | + | + | - | - | + | - | + | + | - | + | + | + | + | + | + | + |
| Pz | | | | | + | + | + | - | - | - | - | + | + | + | + | - | - | - | - | + | + | - | - | - | - | + | - | + | + | + | + | + | + | - |
| P4 | | | | | | - | + | + | + | + | + | - | - | + | - | - | - | - | - | - | - | + | - | - | + | - | - | + | + | - | + | + | + | + |
| P6 | | | | | | | + | + | + | + | + | - | - | + | - | - | - | - | - | - | - | + | - | - | + | - | - | + | + | - | + | - | + | + |
| P5 | | | | | | | | + | + | + | + | - | + | - | + | + | - | + | + | + | + | - | - | + | + | + | + | - | + | + | + | + | + | + |
| P3 | | | | | | | | | - | - | - | + | + | - | + | - | - | - | - | + | + | - | - | - | - | + | - | + | + | + | + | + | + | - |
| Cz | | | | | | | | | | - | + | + | + | + | + | - | - | - | - | + | + | - | - | - | - | + | - | + | + | + | - | + | + | - |
| C3 | | | | | | | | | | | - | - | - | + | - | + | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | + | - |
| C5 | | | | | | | | | | | | - | - | - | - | - | - | - | + | - | - | - | - | + | - | - | - | - | - | + | - | - | - | - |
| C4 | | | | | | | | | | | | | - | + | - | - | + | - | - | - | - | - | + | - | - | + | - | - | + | + | + | - | - | + |
| C6 | | | | | | | | | | | | | | + | - | + | + | - | - | - | - | + | - | - | + | - | + | + | + | - | + | - | - | + |
| T7 | | | | | | | | | | | | | | | + | + | + | + | + | + | + | + | + | + | + | + | + | - | - | + | + | + | + | + |
| T8 | | | | | | | | | | | | | | | | - | + | - | - | - | - | + | - | - | + | - | - | + | + | - | + | - | - | + |
| Fz | | | | | | | | | | | | | | | | | - | - | + | + | + | + | - | - | - | + | - | + | + | - | - | - | - | - |
| F3 | | | | | | | | | | | | | | | | | | - | + | + | + | + | - | + | - | + | - | - | + | + | - | - | + | - |
| F7 | | | | | | | | | | | | | | | | | | | - | + | + | + | - | - | - | - | - | + | + | - | - | - | + | - |
| F4 | | | | | | | | | | | | | | | | | | | | + | + | + | - | - | + | - | + | + | + | - | - | - | - | - |
| F8 | | | | | | | | | | | | | | | | | | | | | - | + | + | + | + | + | + | + | + | - | + | - | - | + |
| FT8 | | | | | | | | | | | | | | | | | | | | | | + | - | + | + | + | + | + | + | - | + | - | - | + |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | + | + | - | + | + | - | + | + | - | + | + | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | + | - | - | - | - | - |
| FP | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | + | + | - | - | - | - | - |

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| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | | + | + | - | + | + | - | + | + | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | | + | + | + | - | - | - | - | + |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | + | + | - | + |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | + | + | + | + | + |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | + | + | + | + |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | + |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | + | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | + |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: p<0.001; -: p>0.001.

*4.2.1.3. Comparison of amplitudes between Kannada and English for semantically correct and semantically incorrect sentences of Group I.*

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of 34 electrodes between Kannada and English for semantically correct and semantically incorrect sentences of Group I. /Z/ values group I for semantically correct sentences and semantically incorrect sentences are given in Table 14.

Table 14.

*Significant differences between Kannada and English for correct sentences group I.*

| Electrode | Semantically Correct sentences | /Z/ | Semantically incorrect sentences | /Z/ |
|---|---|---|---|---|
| O2 | Kan Vs Eng | -2.20* | Kan Vs Eng | -1.344 |
| O1 | Kan Vs Eng | -2.12* | Kan Vs Eng | -3.17** |
| Oz | Kan Vs Eng | -1.79 | Kan Vs Eng | -2.72** |
| Pz | Kan Vs Eng | -1.90 | Kan Vs Eng | -.709 |
| P4 | Kan Vs Eng | -2.68** | Kan Vs Eng | -.373 |
| P6 | Kan Vs Eng | -2.91** | Kan Vs Eng | -.971 |
| P5 | Kan Vs Eng | -1.82 | Kan Vs Eng | -3.13** |
| P3 | Kan Vs Eng | -2.05* | Kan Vs Eng | -2.128* |
| Cz | Kan Vs Eng | -2.12* | Kan Vs Eng | -.037 |
| C3 | Kan Vs Eng | -1.829 | Kan Vs Eng | -1.045 |
| C5 | Kan Vs Eng | -.971 | Kan Vs Eng | -1.493 |
| C4 | Kan Vs Eng | -2.501* | Kan Vs Eng | -1.232 |
| C6 | Kan Vs Eng | -2.8** | Kan Vs Eng | -1.717 |
| T7 | Kan Vs Eng | -.747 | Kan Vs Eng | -3.584** |
| T8 | Kan Vs Eng | -1.717 | Kan Vs Eng | -1.643 |
| Fz | Kan Vs Eng | -1.157 | Kan Vs Eng | -.635 |
| F3 | Kan Vs Eng | -1.344 | Kan Vs Eng | -1.717 |
| F7 | Kan Vs Eng | -.373 | Kan Vs Eng | -2.203* |
| F4 | Kan Vs Eng | -1.493 | Kan Vs Eng | -.112 |
| F8 | Kan Vs Eng | -1.195 | Kan Vs Eng | -1.717 |
| FT8 | Kan Vs Eng | -.859 | Kan Vs Eng | -.896 |
| FT7 | Kan Vs Eng | -.035 | Kan Vs Eng | -1.829 |
| FP1 | Kan Vs Eng | -.149 | Kan Vs Eng | -.075 |
| FP2 | Kan Vs Eng | -.784 | Kan Vs Eng | -.448 |
| FC3 | Kan Vs Eng | -1.568 | Kan Vs Eng | -1.755 |
| FC4 | Kan Vs Eng | -2.203* | Kan Vs Eng | -.448 |
| FCz | Kan Vs Eng | -1.941 | Kan Vs Eng | -.075 |
| CP5 | Kan Vs Eng | -1.493 | Kan Vs Eng | -2.576* |
| TP7 | Kan Vs Eng | -.299 | Kan Vs Eng | -3.509** |
| TP8 | Kan Vs Eng | -2.80** | Kan Vs Eng | -2.203* |

| | | | | |
|---|---|---|---|---|
| CPz | Kan Vs Eng | -2.427* | Kan Vs Eng | -.373 |
| CP4 | Kan Vs Eng | -2.68** | Kan Vs Eng | -1.568 |
| CP6 | Kan Vs Eng | -2.42* | Kan Vs Eng | -2.091* |
| CP3 | Kan Vs Eng | -1.979 | Kan Vs Eng | -1.419 |

Note: *: p<0.05; **: p<0.01.

Comparisons between L1 and L2 have shown differences between processing of L1 and L2 at few electrode sites majorly in O2, O1, P4, P6, P3, Cz, C4, C6, FC4, TP8, CPz, CP4, and CP6 for correct sentences and for semantically incorrect sentences differences were found at O1, Oz, P5, P3, T7, F7, CP5, TP7, TP8, and CP6 indicating subtle differences in processing of each type of sentence in L1 and L2.

**4.2.2. Scalp-*wise analysis of N400 effect in group I in Kannada and English.***

The ERP responses of all eight scalp regions were analyzed and the mean values of responses in the duration of 300-500ms were measured by using independent component analysis of Matlab software for measuring N400 effect in group I. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of eight scalp regions for semantically correct and semantically incorrect sentences in Kannada and English for group I. Table 15 and 16 represent the mean, median and standard deviations and /Z/ values of N400 component for group I for correct sentences and semantically incorrect sentences in Kannada and English respectively.

Table 15.

*Mean, Median and SD values of amplitude of N400 components of eight scalp regions for group I for semantically correct and semantically incorrect sentences in Kannada.*

| **Hemispheric region** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| Left anterior (LA) | .313 | .627 | 1.226 | .206 | .155 | .846 | -.635 |
| Right anterior (RA) | .636 | .574 | .890 | .383 | .478 | .613 | -1.195 |
| Left central (LC) | .152 | .354 | .974 | -.165 | -.301 | .897 | -1.381 |
| Right central (RC) | .266 | .255 | .625 | .130 | .090 | .673 | -.971 |
| Left centro-parietal (LCP) | .022 | .030 | .822 | -.143 | -.120 | .889 | -.896 |
| Right centro-parietal (RCP) | .094 | .140 | .804 | .050 | -.047 | .622 | -.187 |
| Left posterior (LP) | -.161 | -.085 | .847 | -.118 | -.215 | .952 | -.166 |
| Right posterior (RP | .044 | -.024 | .643 | .125 | .060 | .617 | -.154 |

Note: *: p<0.05; **: p<0.01.

Analysis of amplitudes of N400 across eight scalp regions also revealed differences in activation levels across eight scalp regions. In L1, greater negative activation levels (N400) for semantically incorrect sentences were observed for left anterior and posterior, bilateral centro-parietal (CP) and central (C) regions.

Table 16

*Mean, Median and SD values of amplitude of N400 components of eight scalp regions for group I for semantically correct and semantically incorrect sentences in English.*

| **Hemispheric region** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| Left anterior | .500 | .562 | .574 | -.254 | -.201 | .953 | -3.024** |
| Right anterior | .891 | .949 | .588 | .523 | .57 | .758 | -1.568 |
| Left central | .612 | .865 | .958 | -.575 | -.501 | .814 | -3.696** |
| Right central | .266 | .255 | .625 | .984 | 1.03 | .744 | -1.531 |
| Left centro-parietal | .591 | .928 | 1.06 | .591 | .928 | 1.06 | -3.659** |
| Right centro-parietal | .882 | 1.13 | .839 | .629 | .862 | .837 | -.971 |
| Left posterior | .516 | .714 | 1.21 | -.857 | -.871 | .866 | -3.547** |
| Right posterior | .743 | .818 | .800 | .393 | .418 | .712 | -1.904 |

Note: *: $p<0.05$; **: $p<0.01$.

In L2, greater negative activation levels (N400) for semantically incorrect sentences were observed across bilateral anterior and posterior, left central, and right centro-parietal regions. However, these differences were statistically significant at left anterior, left central, left centro-parietal, and left posterior regions as revealed by Wilcoxon signed ranks test in both L1 and L2.

*4.2.2.1. Between scalp region comparison for eight regions for Group I of semantically correct and semantically incorrect sentences in Kannada.*

Friedman test results revealed significant difference between the electrodes for group I ($\chi^2$ (7) = 22.167, $p$ < .05). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between scalp regions in group I for semantically correct sentences. Results of pair-wise comparisons between scalp regions for group I for correct sentences in Kannada are given in Table 17.

Table 17.

*Pair-wise comparisons of eight scalp regions for correct sentences in Kannada for group I.*

| **Scalp region** | **LA** | **RA** | **LC** | **RC** | **LCP** | **RCP** | **LP** | **RP** |
|---|---|---|---|---|---|---|---|---|
| **LA** | | -.971 | -1.344 | -.037 | -1.307 | -.709 | -1.605 | -1.157 |
| **RA** | | | -1.829 | -2.016 | -2.27* | -2.35** | -2.80** | -2.76** |
| **LC** | | | | -.224 | -1.232 | -.299 | -2.053* | -.295 |
| **RC** | | | | | -1.381 | -1.829 | -2.76** | -2.50** |
| **LCP** | | | | | | -.896 | -1.904 | -.485 |
| **RCP** | | | | | | | -2.352* | -1.904 |
| **LP** | | | | | | | | -1.531 |
| **RP** | | | | | | | | |

**: p<0.01. *: p<0.05.

Friedman test results revealed significant difference between the electrodes for Group I for semantically incorrect sentences ($\chi^2$ (7) = 19.80, $p < .05$). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between scalp regions in group I for semantically incorrect sentences in Kannada. Results of pair-wise comparisons between scalp regions for group I for semantically incorrect sentences in Kannada are given in Table 18.

Table 18.

*Pair-wise comparisons of eight scalp regions for incorrect sentences in Kannada for group I.*

| Scalp region | LA | RA | LC | RC | LCP | RCP | LP | RP |
|---|---|---|---|---|---|---|---|---|
| LA | | -.971 | -2.27* | -.672 | -1.87 | -1.01 | -1.34 | -.56 |
| RA | | | -2.87** | -2.28* | -2.65** | -2.77** | -2.46** | -1.90 |
| LC | | | | -1.61 | -.523 | -1.15 | -.485 | -1.19 |
| RC | | | | | -1.53 | -1.82 | -1.27 | -1.01 |
| LCP | | | | | | -.560 | -1.19 | -1.79 |
| RCP | | | | | | | -.709 | -1.16 |
| LP | | | | | | | | -1.64 |
| RP | | | | | | | | |

**: p<0.01. *: p<0.05.

*4.2.2.2. Between scalp region comparison for eight regions for Group I of semantically correct and semantically incorrect sentences in English.*

Friedman test results revealed significant difference between the electrodes for group I in amplitudes of eight scalp regions for semantically correct sentences in English

($\chi^2$ (7) = 17.067, $p$ < .05). Wilcoxon post-hoc analysis of pair-wise comparisons between scalp regions for group I for correct sentences in English are given in Table 19.

Table 19.

*Pair-wise comparisons of eight scalp regions for correct sentences in English for group I.*

| Scalp region | LA | RA | LC | RC | LCP | RCP | LP | RP |
|---|---|---|---|---|---|---|---|---|
| LA | | -3.14** | -.784 | -2.95** | -.672 | -1.904 | -.187 | -.597 |
| RA | | | -.933 | -.747 | -.896 | -.112 | -1.157 | -.672 |
| LC | | | | -2.39* | -1.04 | -1.75 | -1.493 | -1.120 |
| RC | | | | | -2.69** | -1.15 | -2.46* | -2.13* |
| LCP | | | | | | -2.31* | -1.605 | -1.41 |
| RCP | | | | | | | -2.203* | -2.016* |
| LP | | | | | | | | -1.531 |
| RP | | | | | | | | |

**: p<0.01. *: p<0.05.

Friedman test results revealed significant difference between the scalp regions for Group I for semantically incorrect sentences in English ($\chi^2$ (7) = 89.80, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between scalp regions in group I for semantically incorrect sentences. Results of pair-wise comparisons between scalp regions for group I for semantically incorrect sentences in English are given in Table 20.

Table 20.

*Pair-wise comparisons of eight scalp regions for semantically incorrect sentences in English for group I.*

| Scalp region | LA | RA | LC | RC | LCP | RCP | LP | RP |
|---|---|---|---|---|---|---|---|---|
| LA | | -3.88** | -1.792 | -3.62** | -1.792 | -3.58** | -2.128* | -2.539* |
| RA | | | -3.85** | -.560 | -3.66** | -.523 | -3.62** | -.896 |
| LC | | | | -3.92** | -1.605 | -3.88** | -2.315* | -3.90** |
| RC | | | | | -3.7** | -.373 | -3.733** | -2.128* |
| LCP | | | | | | -3.44** | -2.352* | -3.92** |
| RCP | | | | | | | -3.62** | -2.80** |
| LP | | | | | | | | -3.83** |
| RP | | | | | | | | |

**: p<0.01. *: p<0.05.

*4.2.2.3. Comparison of amplitudes between Kannada and English for semantically correct and semantically incorrect sentences of Group I across eight scalp regions.*

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of eight scalp regions between Kannada and English for semantically correct and semantically incorrect sentences for group I. /Z/ values group I are given in Table 21 for semantically correct and semantically incorrect sentences.

Table 21.

*Significant differences between Kannada and English for correct and incorrect sentences in group I.*

| **Scalp region** | **Correct sentences** | **/Z/** | **Semantically incorrect sentences** | **/Z/** |
|---|---|---|---|---|
| Left anterior | Kan Vs Eng | -.448 | Kan Vs Eng | -1.92 |
| Right anterior | Kan Vs Eng | -1.195 | Kan Vs Eng | -.71 |
| Left central | Kan Vs Eng | -1.381 | Kan Vs Eng | -1.232 |
| Right central | Kan Vs Eng | -2.613** | Kan Vs Eng | -1.98* |
| Left centro-parietal | Kan Vs Eng | -1.680 | Kan Vs Eng | -2.02* |
| Right centro-parietal | Kan Vs Eng | -2.501* | Kan Vs Eng | -2.091* |
| Left posterior | Kan Vs Eng | -2.016* | Kan Vs Eng | -2.84** |
| Right posterior | Kan Vs Eng | -2.763** | Kan Vs Eng | -1.083 |

Note: *: $p<0.05$; **: $p<0.01$.

Comparison of amplitudes of L1 and L2 at eight scalp regions showed significant differences between processing of L1 and L2 in correct sentences at right central, right centro-parietal, left posterior and at right posterior. Significant differences between L1 and L2 were found at right central, left centro-parietal, right centro-parietal, left posterior regions for semantically incorrect sentences.

**4.2.3. *Hemispheric activation analysis of N400 effect in group I in Kannada and English.***

The ERP responses of all three hemispheric regions were analyzed and the mean values of responses in the duration of 300-500ms were measured by using independent component analysis of Matlab software for measuring N400 effect in group I. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of three hemispheric regions for semantically correct and semantically incorrect sentences in Kannada and English for group I. Table 22 and 23 represent the mean, median and standard deviations and /Z/ values of N400 component for group I for correct sentences and semantically incorrect sentences in Kannada and English respectively.

Table 22.

*Mean, Median and SD values of amplitude of N400 components of three hemispheric regions for group I for semantically correct and semantically incorrect sentences in Kannada.*

| **Hemispheric region** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| Right hemisphere | .460 | .651 | .255 | .483 | .450 | .537 | -1.195 |
| Central region | -.188 | .755 | -.181 | .081 | .413 | -.007 | -.037 |
| Left hemisphere | .066 | .669 | -.058 | -.241 | .470 | -.310 | -.821 |

Note: *: p<0.05; **: p<0.01.

Table 23.

*Mean, Median and SD values of amplitude of N400 components of three hemispheric regions for group I for semantically correct and semantically incorrect sentences in English.*

| **Hemispheric region** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| Right hemisphere | .046 | .505 | .056 | .091 | .779 | -.072 | -1.680 |
| Central region | -.137 | .712 | -.058 | -.622 | .950 | -.488 | -3.13** |
| Left hemisphere | -.241 | .623 | -.031 | -.794 | .796 | -.680 | -3.92** |

Note: *: p<0.05; **: p<0.01.

Results of hemispheric activation analysis revealed greater negative activation over left hemisphere indicating greater involvement of left hemisphere structures in processing of semantic aspects in L1 and in L2, negative activation is observed for all three regions, left, right and central areas. However, the differences in amplitudes between semantically correct and semantically incorrect sentences are not statistically significant in L1. In L2, statistically significant differences were observed between semantically correct and semantically incorrect sentences over left hemisphere and central regions.

*4.2.3.1. Comparison of three hemispheric regions of group I for semantically correct sentences in Kannada.*

Friedman test results revealed significant difference between three hemispheric regions for Group I ($\chi^2$ (2) = 7.30, $p$ < .05) for semantically correct sentences. Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between hemispheric regions in group I for each type of sentence. Results of Wilcoxon tests in Kannada are given in Table 24 for group I.

Table 24.

*Pair-wise comparisons of three hemispheric regions for correct sentences in Kannada for clinical group.*

| | Right hemisphere | Central region | Left hemisphere |
|---|---|---|---|
| Right hemisphere | | -2.949** | -1.381 |
| Central region | | | -.859 |
| Left hemisphere | | | |

**: p<0.01.

However, no significant difference was found between hemispheric regions for semantically incorrect sentences in group I ($\chi^2$ (2) = 5.70, $p$ > .05). Pair-wise analysis between hemispheres also revealed significant differences in activation levels between right and central regions for correct sentences in Kannada. For semantically incorrect sentences in Kannada, no significant differences were found between all three regions.

*4.2.3.2. Comparison of three hemispheric regions of group I for semantically correct sentences in English.*

Friedman test results revealed significant difference between three hemispheric regions for Group I ($\chi^2$ (2) = 17.50, $p$ < .01) for semantically correct sentences in English. Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between hemispheric regions in group I for each type of sentence. Results of Wilcoxon tests in English are given in Table 25 for group I.

Table 25.

*Pair-wise comparisons of three hemispheric regions for semantically correct sentences in English for group I.*

| | Right hemisphere | Central region | Left hemisphere |
|---|---|---|---|
| Right hemisphere | | -3.472** | -2.837** |
| Central region | | | -.448 |
| Left hemisphere | | | |

**: p<0.01.

Results of Friedman test also revealed significant differences between three hemispheric regions for semantically incorrect sentences for Group I ($\chi^2$ (2) = 34.90, $p$ < .01). Wilcoxon post hoc test results are given in Table 26 for semantically incorrect sentences in English for Group I.

Table 26.

*Pair-wise comparisons of three hemispheric regions for incorrect sentences in English for group I.*

| | Right hemisphere | Central region | Left hemisphere |
|---|---|---|---|
| Right hemisphere | | -3.921** | -3.920** |
| Central region | | | -3.173** |
| Left hemisphere | | | |

**: p<0.01.

The above results showed that in English (L2), differences were found between right to left and right to central hemispheres for both semantically correct and semantically incorrect sentences.

*4.2.3.3. Comparison of amplitudes between Kannada and English for semantically correct and semantically incorrect sentences of Group I across three hemispheric regions.*

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of three hemispheric regions between Kannada and English for semantically correct and semantically incorrect sentences for group I. /Z/ values group I are given in Table 27 for semantically correct and semantically incorrect sentences.

Table 27.

*Significant differences between Kannada and English for correct and incorrect sentences in group I.*

| | Correct sentences | /Z/ | Semantically incorrect sentences | /Z/ |
|---|---|---|---|---|
| Right hemisphere | Kan Vs Eng | -2.427* | Kan Vs Eng | -1.419 |
| Central hemisphere | Kan Vs Eng | -2.165* | Kan Vs Eng | -.896 |
| Left hemisphere | Kan Vs Eng | -1.493 | Kan Vs Eng | -2.464* |

Note: *:p<0.05.

Comparisons of hemispheric activation levels between L1 and L2 revealed significant differences in right hemisphere and central regions for semantically correct sentences and for semantically incorrect sentences significant differences were found in left hemisphere. These results also revealed involvement of both the hemispheres in processing of semantic violations in both L1 and L2.

***General discussion on semantic processing in participants with aphasia***

The results of present study revealed activation of both left and right hemispheres during processing of semantically incorrect sentences in both L1 and L2. However, the level of activation is higher in right hemispheric regions for L2 than in L1. These results are supported by few of the previous studies by Becker and Reinvang (2007), D'Arcy et al (2003), and Swaab et al (1997) who have reported symmetrical activation in both right and left hemispheres in individuals with aphasia during semantic processing. Topographical analysis done by Becker and Reinvang (2007) has reported symmetrical activation in early processing and differential activation in late ERP components on syllable detection task. While in severe aphasics, differential activation was observed during early processing and symmetrical activation was observed for late ERP components indicating the effect of severity of aphasia on processing abilities of language. The study also provided evidence for differences in processing levels vary depending on factors such as site of lesion, post onset duration and modality of task. Study by D'Arcy et al (2003) has provided major support for usage of electrophysiological methods in assessment of language processing abilities in individuals with aphasia following stroke. Results revealed presence of N400 component at around 500 ms for semantically incongruent stimuli on PPVT-R test.

Topographical analysis of N400 component revealed significant activation at centro-parietal regions with largest amplitudes at Pz electrode site. They have also found significant correlation between the scores of PPVT-R and ERP data which suggested that ERPs can be used as an assessment tool in understanding the language processing in individuals with aphasia.

Swaab et al (1997) also reported similar results on processing of semantically anomalous sentences in individuals with aphasia on N400 component. Results revealed presence o N400 component in individuals with moderate to severe aphasia and it is significantly different to that of healthy controls on semantic judgment task. Similar results were also reported by Hagoort et al (1996), and Freiderici et al (1999) who attributed the results to impairments in integrating word meanings into an overall meaningful representation by individuals with aphasia.

#### **4.3.1.** ***Electrode-wise analysis of P600 effect in group I in Kannada and English.***

The ERP responses of all 34 electrodes were analyzed and the mean values of responses in the duration of 500-700ms were measured by using independent component analysis of Matlab software for measuring P600 effect in group I. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of 34 electrodes for syntactically correct and syntactically incorrect sentences in Kannada for group I. Table 28 and 29 represent the mean, median and standard deviations and /Z/ values of N400 component for group I for syntactically correct sentences and syntactically incorrect sentences in Kannada and English respectively.

Table 28.

*Mean, Median and SD values of amplitude of P600 components for group I for syntactically correct and syntactically incorrect sentences in Kannada.*

| Electrode | Amplitudes for Semantically correct sentences | | | Amplitudes for Semantically incorrect sentences | | | /Z/ |
|---|---|---|---|---|---|---|---|
| | Mean (in µv) | Median | SD (in µv) | Mean (in µv) | Median | SD (in µv) | |
| O2 | -.713 | -.726 | .539 | .125 | .175 | .406 | -3.54** |
| O1 | -.631 | -.49 | .648 | -.401 | -.52 | .776 | -.709 |
| Oz | -.428 | -.418 | .657 | -.030 | .069 | .528 | -2.42* |
| Pz | -.08 | -.063 | .585 | -.18 | -.31 | .61 | -.597 |
| P4 | -.100 | -.190 | .605 | -.33 | -.305 | .835 | -1.083 |
| P6 | .040 | -.02 | .61 | -.201 | -.247 | .551 | -1.568 |
| P5 | -.507 | -.226 | .737 | -.363 | -.535 | .520 | -.336 |
| P3 | -.335 | -.322 | .429 | -.273 | -.494 | .551 | -.261 |
| Cz | -.244 | -.260 | .765 | -.496 | -.583 | .803 | -.896 |
| C3 | -.340 | -.277 | .649 | -.342 | -.23 | .722 | -.075 |
| C5 | .101 | .026 | 1.112 | -.277 | -.124 | .628 | -1.344 |
| C4 | -.028 | .156 | .889 | -.22 | -.36 | .622 | -.859 |
| C6 | .172 | .236 | .873 | -.363 | -.542 | .594 | -2.053* |
| T7 | .038 | .100 | .88 | -.142 | -.214 | .655 | -.933 |
| T8 | .091 | .145 | .883 | -.24 | -.09 | .875 | -.672 |
| Fz | .088 | .173 | .984 | -.699 | -.669 | 1.089 | -2.68** |
| F3 | .097 | .402 | 1.042 | -.420 | -.302 | .816 | -1.904 |
| F7 | .206 | .143 | 1.12 | -.181 | -.357 | 1.093 | -1.157 |
| F4 | .186 | .200 | 1.03 | -.383 | -.403 | .727 | -2.16* |
| F8 | .518 | .764 | 1.034 | .021 | .22 | .770 | -1.792 |
| FT8 | .265 | .406 | .858 | .032 | .239 | 1.033 | -.597 |
| FT7 | .350 | .385 | 1.07 | -.272 | -.373 | .888 | -2.315* |
| FP1 | 1.00 | 1.26 | 1.08 | -.248 | -.130 | .929 | -3.21** |
| FP2 | .987 | .91 | 1.126 | .331 | .256 | .909 | -1.941 |
| FC3 | -.152 | .084 | .923 | -.497 | -.446 | .795 | -1.568 |
| FC4 | .092 | .210 | .993 | -.397 | -.43 | .686 | -1.867 |
| FCz | -.408 | -.245 | .977 | -.797 | -.887 | 1.034 | -1.381 |
| CP5 | -.328 | -.155 | .820 | -.177 | -.168 | .545 | -.411 |
| TP7 | -.592 | -.381 | .927 | -.419 | -.401 | .636 | -.784 |
| TP8 | .168 | .090 | .60 | -.22 | -.207 | .544 | -1.867 |
| CPz | -.168 | -.115 | .658 | -.206 | -.361 | .661 | -.149 |
| CP4 | -.008 | .163 | .918 | -.20 | -.524 | .646 | -.933 |
| CP6 | .096 | .168 | .72 | -.089 | -.039 | .519 | -.940 |
| CP3 | -.373 | -.421 | .519 | -.293 | -.497 | .690 | -.411 |

Note: *: p<0.05; **: p<0.01.

In L1, P600 component (positive shift in amplitudes) for syntactically incorrect sentences was observed only at C6, Fz, FT7, FP1, O2 and Oz indicating presence of P600 in L1 in individuals with aphasia in the duration of 500-700ms of standard time window only at few electrode sites.

Table 29.

*Mean, Median and SD values of amplitude of P600 components for group I for syntactically correct and syntactically incorrect sentences in English.*

| **Electrode** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| O2 | -.207 | -.010 | .832 | -.596 | -.689 | .916 | -1.269 |
| O1 | -.606 | -.549 | 1.080 | -.338 | -.35 | .910 | -.859 |
| Oz | -.350 | -.237 | .738 | -.723 | -.55 | .862 | -1.568 |
| Pz | -.322 | -.375 | .779 | .078 | .101 | .847 | -1.829 |
| P4 | -.205 | -.065 | .807 | .11 | .16 | .69 | -1.755 |
| P6 | -.27 | -.122 | .712 | .104 | .172 | .925 | -1.755 |
| P5 | -.410 | -.45 | 1.023 | -.076 | -.023 | 1.360 | -1.195 |
| P3 | -.45 | -.413 | .808 | -.037 | .025 | .840 | -2.016* |
| Cz | -.396 | -.315 | .747 | .188 | -.030 | 1.054 | -1.904 |
| C3 | -.264 | -.251 | .910 | .41 | .32 | .928 | -2.80** |
| C5 | .057 | .410 | .993 | .345 | .489 | 1.064 | -1.755 |
| C4 | -.296 | -.112 | .843 | .26 | .305 | 1.02 | -2.315* |
| C6 | -.180 | -.223 | .774 | .292 | .35 | .940 | -1.829 |
| T7 | .138 | -.08 | .922 | .293 | .524 | 1.238 | -.523 |
| T8 | .015 | .066 | .752 | .205 | .210 | 1.225 | -.896 |
| Fz | -.098 | -.168 | .735 | .392 | .179 | 1.075 | -1.867 |
| F3 | -.002 | -.134 | .709 | .583 | .280 | .961 | -2.501* |
| F7 | -.086 | -.119 | .880 | .51 | .08 | 1.049 | -2.35* |
| F4 | -.160 | -.175 | .788 | .361 | .370 | 1.037 | -1.829 |
| F8 | -.171 | -.302 | .938 | .443 | .571 | 1.22 | -2.016* |
| FT8 | -.117 | -.141 | .860 | .353 | .730 | 1.262 | -1.717 |
| FT7 | .19 | .367 | .760 | .627 | .765 | 1.139 | -1.680 |
| FP1 | .288 | .003 | 1.333 | .66 | 1.01 | 1.41 | -.784 |
| FP2 | .038 | .163 | 1.057 | .56 | .763 | 1.134 | -2.128* |
| FC3 | -.103 | -.104 | .838 | .418 | .44 | .99 | -2.352* |
| FC4 | -.275 | -.099 | .755 | .349 | .497 | 1.161 | -2.165* |
| FCz | -.309 | -.161 | .729 | .097 | -.071 | 1.16 | -1.307 |
| CP5 | -.319 | -.13 | .905 | .127 | .313 | 1.131 | -1.904 |
| TP7 | .009 | .080 | 1.110 | -.271 | -.360 | 1.426 | -.859 |
| TP8 | -.008 | .094 | .785 | .071 | .047 | .955 | -.560 |
| CPz | -.36 | -.210 | .835 | .074 | -.06 | .702 | -2.165* |
| CP4 | -.251 | -.112 | .826 | .20 | .15 | .88 | -2.315* |
| CP6 | -.065 | .013 | .872 | .22 | .33 | .98 | -1.344 |
| CP3 | -.462 | -.401 | .969 | .115 | .083 | .872 | -2.65** |

Note: *: p<0.05; **: p<0.01.

While in L2, P600 component for syntactically incorrect sentences was observed at O1, Pz, P4, P6, P5, P3, Cz, C3, C4, T7, T8, Fz, F3, F7, F4, FT8, FT7, FC3, FC4, CP5, CP4, and CP3. However, significant differences between amplitudes of syntactically correct and syntactically incorrect sentences were observed at only right occipital (O2), central occipital (Oz), right central (C6), fronto-central (Fz), right frontal (F4) and left fronto-temporal (FT7) regions. These results indicate that the differential areas are activated during processing of syntactic information in L1 and L2 in bilingual individuals with aphasia. These results also indicated that individuals with aphasia have language processing deficits in L1 than in L2 at central level. Figure 8 and 9 represent the grand average waveforms of P600 components of group I in Kannada and English respectively.

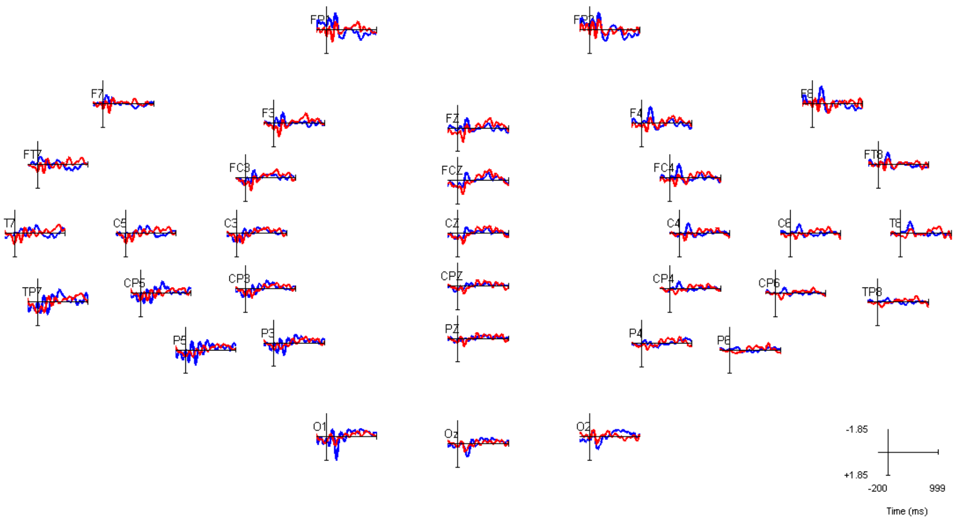

*Figure 8*. Grand average waveforms of 34 electrodes of Group I for syntactically correct and syntactically incorrect sentences in Kannada.

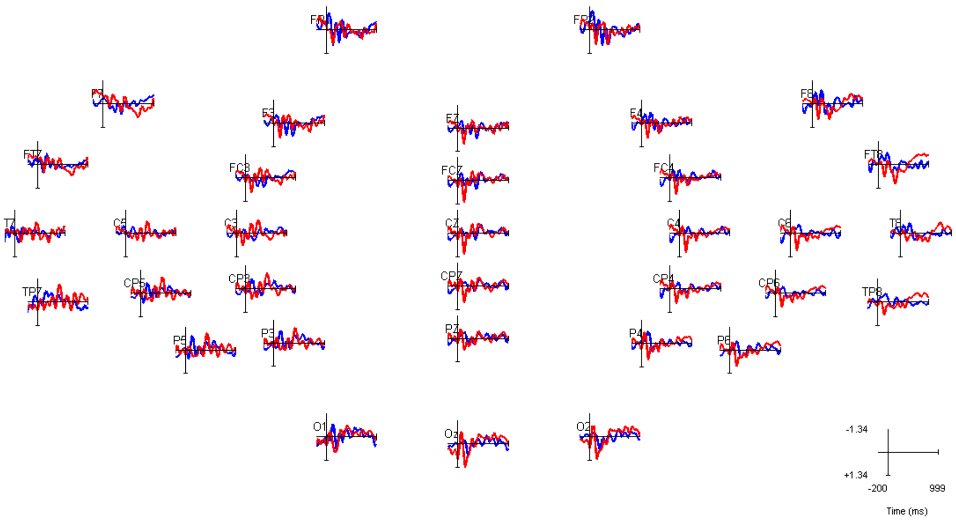

*Figure 9*. Grand average waveforms of 34 electrodes of Group I for syntactically correct and syntactically incorrect sentences in English.

*4.3.1.1. Between electrode comparison for 34 electrodes for Group I of semantically correct and semantically incorrect sentences in Kannada.*

Friedman test was conducted to evaluate the differences in amplitudes of 34 electrodes for syntactically correct sentences in Kannada and results revealed significant difference between the electrodes for group I ($\chi^2$ (33) = 172.33, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group I for each type of sentence. Results of pair-wise comparisons between electrodes for group I for syntactically correct sentences in Kannada are given in Table 30.

Table 30.

*Post-hoc results of pair-wise comparisons of 34 electrodes for syntactically correct sentences in Kannada for group I.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | + | - | - | - | - |
| O1 | | | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | + | + | + | - | - | - | - | - | + | - | - | - | - |
| Oz | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | - |
| Pz | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | - |
| P4 | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | - |
| P6 | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | + |
| P5 | | | | | | | | - | - | - | - | - | - | + | - | - | - | - | - | + | - | - | + | + | - | - | - | - | - | + | - | - | - | - |
| P3 | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | + | - | - | + | + | - | - | - | - | - | - | - | - | - | - |
| Cz | | | | | | | | | | - | - | - | - | + | - | - | - | - | - | + | + | + | - | + | + | - | - | - | - | + | - | - | - | - |
| C3 | | | | | | | | | | | - | - | + | - | - | - | - | - | - | + | + | + | + | + | - | - | - | - | - | + | - | - | - | - |
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| C4 | | | | | | | | | | | | | - | - | - | - | - | - | - | + | + | - | + | + | - | - | - | - | - | - | - | - | - | - |
| C6 | | | | | | | | | | | | | | - | - | - | - | - | - | + | - | - | + | + | - | - | + | - | - | - | - | - | - | + |
| T7 | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | + | - | - | - | - | - | + | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | - |
| Fz | | | | | | | | | | | | | | | | | - | - | - | - | - | - | + | + | - | - | + | - | - | - | - | - | - | - |
| F3 | | | | | | | | | | | | | | | | | | - | - | + | - | - | + | + | - | - | - | - | - | - | - | - | - | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | - |

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| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | + | + | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | + | + | + | + | + | + | + | + | + | + |
| FP2 | | | | | | | | | | | | | | | | | | | | | | | | | + | + | + | + | + | + | + | + | + | + |
| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | + |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | + | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: p<0.001; -: p>0.001.

Friedman test results revealed significant difference between the electrodes for Group I for syntactically incorrect sentences ($\chi^2$ (33) = 89.22, $p < .01$). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group I for syntactically incorrect sentences. Results of pair-wise comparisons between electrodes for group I for semantically incorrect sentences in Kannada are given in Table 31.

Table 31.

*Post-hoc results of pair-wise comparisons of 34 electrodes for syntactically incorrect sentences in Kannada for group I.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
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| O2 | | - | - | - | - | - | + | + | + | + | - | - | + | - | - | - | - | - | - | - | - | - | - | - | + | - | + | - | + | - | - | - | - | - |
| O1 | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oz | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Pz | | | | | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - |
| P4 | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P6 | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P5 | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P3 | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - |
| Cz | | | | | | | | | | - | - | + | - | - | - | - | - | - | - | - | - | - | - | + | - | - | + | - | - | - | + | + | - | - |
| C3 | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - |
| C5 | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - |
| C4 | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - |
| C6 | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - |
| T7 | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Fz | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - |
| F3 | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F4 | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F8 | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - |
| FP | | | | | | | | | | | | | | | | | | | | | | | | | + | + | + | + | - | - | - | - | - | - |

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| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | - | - | - | - | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | + | + | + | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: $p<0.001$; -: $p>0.001$.

*4.3.1.2. Between electrode comparison for 34 electrodes for Group I of syntactically correct and syntactically incorrect sentences in English.*

Friedman test was conducted to evaluate the differences in amplitudes of 34 electrodes for syntactically correct sentences in English and results revealed significant difference between the electrodes for group I ($\chi^2$ (33) = 63.391, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group I for each type of sentence. Results of pair-wise comparisons between electrodes for group I for syntactically correct sentences in English are given in Table 32.

Table 32.

*Pair-wise comparisons of 34 electrodes for syntactically correct sentences in English for group I.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| O1 | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oz | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Pz | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P4 | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P6 | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P5 | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - |
| P3 | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - |
| Cz | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C3 | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C5 | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + |
| C4 | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - |
| C6 | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T7 | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Fz | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F3 | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F4 | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F8 | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - |
| FP | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - |

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| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: p<0.001; -: p>0.001.

Friedman test results revealed significant difference between the electrodes for Group I for syntactically incorrect sentences in English ($\chi^2$ (33) = 54.635, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group I for syntactically incorrect sentences. Results of pair-wise comparisons between electrodes for group I for syntactically incorrect sentences in English are given in Table 33.

Table 33.

*Pair-wise comparisons of 34 electrodes for syntactically incorrect sentences in English for group I.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - |
| O1 | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oz | | | | - | + | + | - | - | - | - | - | - | + | - | - | - | - | + | + | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - |
| Pz | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P4 | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P6 | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P5 | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P3 | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cz | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C3 | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C5 | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C4 | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C6 | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T7 | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Fz | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F3 | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F4 | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F8 | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FP2 | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - |
| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: p<0.001; -: p>0.001.

4.3.1.3. Comparison of amplitudes between Kannada and English for syntactically correct and syntactically incorrect sentences of Group I.

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of 34 electrodes between Kannada and English for syntactically correct and syntactically incorrect sentences of Group I. /Z/ values group I for syntactically correct sentences and syntactically incorrect sentences are given in Table 34.

Table 34.

*Significant differences between Kannada and English for syntactically correct and syntactically incorrect sentences in group I.*

| Electrode | Correct sentences | /Z/ | Syntactically incorrect sentences | /Z/ |
|---|---|---|---|---|
| O2 | Kan Vs Eng | -1.941 | Kan Vs Eng | -2.613** |
| O1 | Kan Vs Eng | -.224 | Kan Vs Eng | -.187 |
| Oz | Kan Vs Eng | -.597 | Kan Vs Eng | -2.80** |
| Pz | Kan Vs Eng | -.448 | Kan Vs Eng | -.859 |
| P4 | Kan Vs Eng | -.45 | Kan Vs Eng | -1.568 |
| P6 | Kan Vs Eng | -.672 | Kan Vs Eng | -1.195 |
| P5 | Kan Vs Eng | -.187 | Kan Vs Eng | -.709 |
| P3 | Kan Vs Eng | -.523 | Kan Vs Eng | -.523 |
| Cz | Kan Vs Eng | -.635 | Kan Vs Eng | -2.501 |
| C3 | Kan Vs Eng | -.187 | Kan Vs Eng | -2.69** |
| C5 | Kan Vs Eng | -.485 | Kan Vs Eng | -2.165* |
| C4 | Kan Vs Eng | -.859 | Kan Vs Eng | -2.240* |
| C6 | Kan Vs Eng | -1.381 | Kan Vs Eng | -2.576* |
| T7 | Kan Vs Eng | -.037 | Kan Vs Eng | -1.456 |
| T8 | Kan Vs Eng | -.448 | Kan Vs Eng | -1.531 |
| Fz | Kan Vs Eng | --.597 | Kan Vs Eng | -3.248** |
| F3 | Kan Vs Eng | -.784 | Kan Vs Eng | -3.323** |
| F7 | Kan Vs Eng | -1.531 | Kan Vs Eng | -2.203* |
| F4 | Kan Vs Eng | -1.232 | Kan Vs Eng | -2.501 |
| F8 | Kan Vs Eng | -2.427* | Kan Vs Eng | -1.792 |
| FT8 | Kan Vs Eng | -1.232 | Kan Vs Eng | -1.867 |
| FT7 | Kan Vs Eng | -.859 | Kan Vs Eng | -2.613** |
| FP1 | Kan Vs Eng | -2.016* | Kan Vs Eng | -2.24* |
| FP2 | Kan Vs Eng | -2.501* | Kan Vs Eng | -1.195 |
| FC3 | Kan Vs Eng | -.149 | Kan Vs Eng | -3.248** |
| FC4 | Kan Vs Eng | -1.493 | Kan Vs Eng | -2.763** |

| | | | | |
|---|---|---|---|---|
| FCz | Kan Vs Eng | -.597 | Kan Vs Eng | -2.987** |
| CP5 | Kan Vs Eng | -.299 | Kan Vs Eng | -1.307 |
| TP7 | Kan Vs Eng | -1.755 | Kan Vs Eng | -.187 |
| TP8 | Kan Vs Eng | -.075 | Kan Vs Eng | -1.419 |
| CPz | Kan Vs Eng | -.597 | Kan Vs Eng | -1.232 |
| CP4 | Kan Vs Eng | -.523 | Kan Vs Eng | -1.792 |
| CP6 | Kan Vs Eng | -.411 | Kan Vs Eng | -1.792 |
| CP3 | Kan Vs Eng | -.261 | Kan Vs Eng | -1.307 |

Note: **: $p<0.01$; *: $p<0.05$.

Comparison between L1 and L2 revealed significant differences between amplitudes of syntactically correct and syntactically incorrect sentences were observed at only right occipital (O2), central occipital (Oz), right central (C6), fronto-central (Fz), right frontal (F4) and left fronto-temporal (FT7) regions. These results indicate that the differential areas are activated during processing of syntactic information in L1 and L2 in bilingual individuals with aphasia. These results also indicated that individuals with aphasia have language processing deficits in L1 than in L2 at central level.

***4.2.2. Scalp region-wise analysis of P600 effect in group I in Kannada and English.***

The ERP responses of all eight scalp regions were analyzed and the mean values of responses in the duration of 500-700ms were measured by using independent component analysis of Matlab software for measuring P600 effect in group I. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of eight scalp regions for syntactically correct and syntactically incorrect sentences in Kannada and English for group I. Table 35 and 36 represent the mean, median and standard deviations and /Z/ values of P600 component for group I for correct sentences and syntactically incorrect sentences in Kannada and English respectively.

Table 35.

*Mean, Median and SD values of amplitude of P600 components of eight scalp regions for group I for syntactically correct and syntactically incorrect sentences in Kannada.*

| **Hemispheric region** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| Left anterior | .300 | .532 | .950 | -.324 | -.275 | .825 | -2.389* |
| Right anterior | .410 | .487 | .964 | -.088 | .111 | .682 | -1.493 |
| Left central | .355 | .721 | .914 | -.206 | -.080 | .673 | -2.343* |
| Right central | .382 | .572 | .928 | -.147 | .011 | .655 | -2.016* |
| Left centro-parietal | .369 | .625 | .918 | -.177 | -.037 | .659 | -2.277* |
| Right centro-parietal | .375 | .593 | .923 | -.162 | .002 | .656 | -2.091* |
| Left posterior | .375 | .604 | .920 | -.169 | -.010 | .657 | -2.166* |
| Right posterior | .374 | .599 | .921 | -.166 | -.001 | .656 | -2.165* |

Note: *: p<0.05; **: p<0.01.

Analysis of amplitudes of P600 across eight scalp regions also revealed differences in activation levels across eight scalp regions. In L1, higher positive activation levels (P600) for syntactically incorrect sentences were not observed for any scalp regions.

Table 36.

*Mean, Median and SD values of amplitude of P600 components of eight scalp regions for group I for syntactically correct and syntactically incorrect sentences in English.*

| Hemispheric region | Amplitudes for Semantically correct sentences | | | Amplitudes for Semantically incorrect sentences | | | /Z/ |
|---|---|---|---|---|---|---|---|
| | Mean (in µv) | Median | SD (in µv) | Mean (in µv) | Median | SD (in µv) | |
| Left anterior | .057 | -.011 | .681 | .552 | .568 | .761 | -2.203* |
| Right anterior | -.127 | -.146 | .677 | .481 | .626 | 1.041 | -2.399* |
| Left central | -.059 | -.072 | .651 | .481 | .464 | .647 | -2.688** |
| Right central | -.118 | -.047 | .705 | .412 | .600 | .848 | -2.464* |
| Left centro-parietal | -.089 | -.044 | .672 | .402 | .650 | .762 | -2.464* |
| Right centro-parietal | -.082 | -.046 | .635 | .392 | .642 | .878 | -2.427* |
| Left posterior | -.066 | -.045 | .610 | .407 | .647 | .831 | -2.389* |
| Right posterior | -.070 | -.046 | .614 | .399 | .646 | .854 | -2.451* |

Note: *: $p<0.05$; **: $p<0.01$.

In L2, higher positive activation levels (P600 component) for syntactically incorrect sentences were observed at all eight scalp regions. However, significant differences were found between syntactically correct and syntactically incorrect sentences at all eight scalp regions.

*4.3.2.1. Comparison of eight scalp regions for Group I of syntactically correct and syntactically incorrect sentences in Kannada.*

Friedman test was conducted to investigate the scalp region activation differences in amplitudes of eight regions for correct sentences in Kannada and results revealed no significant difference between the regions for syntactically correct sentences ($\chi^2$ (7) = 5.87, $p$ > .05) and also for syntactically incorrect sentences ($\chi^2$ (7) = 3.451, $p$ > .05) for group I.

*4.3.2.2. Between scalp region comparison for eight regions for Group I of syntactically correct and syntactically incorrect sentences in English.*

Friedman test was conducted to investigate the scalp region activation differences in amplitudes of eight regions for correct sentences in Kannada and results revealed no significant difference between the regions for syntactically correct sentences ($\chi^2$ (7) = 4.150, $p$ > .05) and also for syntactically incorrect sentences ($\chi^2$ (7) = 2.067, $p$ > .05) for group I.

*4.2.2.3. Comparison of amplitudes between Kannada and English for syntactically correct and syntactically incorrect sentences of Group I across eight scalp regions.*

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of eight scalp regions between Kannada and English for syntactically correct and syntactically incorrect sentences for group I. /Z/ values group I are given in Table 37 for syntactically correct and syntactically incorrect sentences.

Table 37.

*Significant differences between Kannada and English for* syntactically *correct and* syntactically *incorrect sentences in group I.*

| **Scalp region** | **Correct sentences** | **/Z/** | **Semantically incorrect sentences** | **/Z/** |
|---|---|---|---|---|
| Left anterior | Kan Vs Eng | -1.381 | Kan Vs Eng | -3.173** |
| Right anterior | Kan Vs Eng | -2.016* | Kan Vs Eng | -2.527* |
| Left central | Kan Vs Eng | -1.792 | Kan Vs Eng | -3.211** |
| Right central | Kan Vs Eng | -2.016* | Kan Vs Eng | -2.688** |
| Left centro-parietal | Kan Vs Eng | -1.904 | Kan Vs Eng | -2.80** |
| Right centro-parietal | Kan Vs Eng | -2.539* | Kan Vs Eng | -1.941 |
| Left posterior | Kan Vs Eng | -1.942 | Kan Vs Eng | -2.763** |
| Right posterior | Kan Vs Eng | -1.996 | Kan Vs Eng | -2.621** |

Note: *: p<0.05; **: p<0.01.

Comparison between activation levels in L1 and L2 for each type of sentence across eight scalp regions revealed significant differences between two languages at right anterior, right central and right centro-parietal regions for syntactically correct sentences. For syntactically incorrect sentences, significant differences were observed at left anterior, right anterior, left central, right central, left centro-parietal, left posterior and right posterior regions.

### 4.3.3. *Hemispheric activation analysis of P600 effect in group I in Kannada and English.*

The ERP responses of all three hemispheric regions were analyzed and the mean values of responses in the duration of 500-700ms were measured by using independent component analysis of Matlab software for measuring P600 effect in group I. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of three hemispheric regions for syntactically correct and syntactically incorrect sentences in Kannada and English for group I. Table 38 and 39 represent the mean, median and standard deviations and /Z/ values of P600 component for group I for syntactically correct sentences and syntactically incorrect sentences in Kannada and English respectively.

Table 38.

*Mean, Median and SD values of amplitude of P600 components of three hemispheric regions for group I for* syntactically *correct and* syntactically *incorrect sentences in Kannada.*

| **Hemispheric region** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| Right hemisphere | .126 | .693 | .166 | -.154 | .527 | -.089 | -1.269 |
| Central region | -.208 | .569 | -.140 | -.402 | .70 | -.521 | -.709 |
| Left hemisphere | -.105 | .654 | -.267 | -.307 | .520 | -.267 | -1.120 |

Note: *: p<0.05; **: p<0.01.

Results of hemispheric activation analysis in L1 revealed no positive activation for syntactically incorrect sentences than syntactically correct sentences in left, right and central areas.

Table 39.

*Mean, Median and SD values of amplitude of P600 components of three hemispheric regions for group I for syntactically correct and syntactically incorrect sentences in English.*

| Hemispheric region | Amplitudes for Semantically correct sentences | | | Amplitudes for Semantically incorrect sentences | | | /Z/ |
|---|---|---|---|---|---|---|---|
| | Mean (in µv) | Median | SD (in µv) | Mean (in µv) | Median | SD (in µv) | |
| Right hemisphere | -.140 | .643 | -.034 | .222 | .809 | .297 | -1.755 |
| Central region | -.307 | .648 | -.205 | -.016 | .594 | -.072 | -1.568 |
| Left hemisphere | -.169 | .739 | -.276 | .221 | .797 | .276 | -2.427* |

Note: *: p<0.05; **: p<0.01.

The above results indicated that in L2, positive activation for syntactically incorrect sentences (P600 component) is observed in both right and left hemispheres although the difference is statistically significant in left hemisphere.

*4.3.3.1. Comparison of three hemispheric regions of group I for syntactically correct and incorrect sentences in Kannada.*

Friedman test results revealed significant difference between three hemispheric regions for Group I ($\chi^2$ (2) = 6.70, $p$ < .05) for syntactically correct sentences. Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between hemispheric regions in group I for each type of sentence. Results of Wilcoxon tests in Kannada are given in Table 40 for group I.

Table 40.

*Pair-wise comparisons of three hemispheric regions for syntactically correct sentences in Kannada for clinical group.*

| | Right hemisphere | Central region | Left hemisphere |
|---|---|---|---|
| Right hemisphere | | -3.323** | -1.456 |
| Central region | | | -.784 |
| Left hemisphere | | | |

**: p<0.01.

However, no significant difference was found between hemispheric regions for semantically incorrect sentences in group I ($\chi^2$ (2) = 3.60, $p$ > .05).

*4.3.3.2. Comparison of three hemispheric regions of group I for syntactically correct and incorrect sentences in English.*

Friedman test results revealed no significant difference between three hemispheric regions for Group I for syntactically correct sentences ($\chi^2$ (2) = 3.70, $p$ > .05) and syntactically incorrect sentences ($\chi^2$ (2) = 3.60, $p$ > .05) in English.

*4.3.3.3. Comparison of amplitudes between Kannada and English for syntactically correct and syntactically incorrect sentences of Group I across three hemispheric regions.*

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of three hemispheric regions between Kannada and English for syntactically correct and syntactically incorrect sentences for group I. /Z/ values group I are given in Table 41 for syntactically correct and syntactically incorrect sentences.

Table 41.

*Significant differences between Kannada and English for* syntactically *correct and* syntactically *incorrect sentences in group I.*

| | Correct sentences | /Z/ | Syntactically incorrect sentences | /Z/ |
|---|---|---|---|---|
| Right hemisphere | Kan Vs Eng | -.896 | Kan Vs Eng | -2.016* |
| Central hemisphere | Kan Vs Eng | -.075 | Kan Vs Eng | -1.941 |
| Left hemisphere | Kan Vs Eng | -.672 | Kan Vs Eng | -2.389* |

Note: *: p<0.05.

Comparison between activation levels in L1 and L2 for each type of sentence across three hemispheric regions revealed no significant difference in three hemispheric regions for syntactically correct sentences but significant differences were found in right and left hemispheres for syntactically incorrect sentences.

Two studies carried out by Justus et al (2011) and Friederici et al (1999) have also reported impaired syntactic processing in individuals with aphasia. Friederici et al (1999) have reported presence of P600 component in individuals with left hemisphere cortical lesions and left subcortical lesions although the level of activation is reduced and latency is delayed indicating slower processing of syntactic information in pathological conditions. However, there are no studies on syntactic processing in bilinguals with aphasia.

**Objective 2: To explore neural representations of L1 and L2 in normal bilingual participants.**

**4.4.1.** ***Electrode-wise analysis of N400 effect in group II in Kannada and English.***

The ERP responses of all 34 electrodes were analyzed and the mean values of responses in the duration of 300-500ms were measured by using independent component analysis of Matlab software for measuring N400 effect in group II. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of 34 electrodes for semantically correct and semantically incorrect sentences in Kannada for group II. Table 42 and 43 represent the mean, median and standard deviations and /Z/ values of N400 component for group II for correct sentences and semantically incorrect sentences in Kannada and English respectively.

Table 42.

*Mean, Median and SD values of amplitude of N400 components for group II for semantically correct and semantically incorrect sentences in Kannada.*

| Electrode | Amplitudes for Semantically correct sentences | | | Amplitudes for Semantically incorrect sentences | | | /Z/ |
|---|---|---|---|---|---|---|---|
| | Mean (in µv) | Median | SD (in µv) | Mean (in µv) | Median | SD (in µv) | |
| O2 | -.478 | -.097 | .857 | -.141 | -.001 | .432 | -1.269 |
| O1 | -.840 | -.755 | 1.070 | -.72 | -.789 | .650 | -.523 |
| Oz | -.607 | -.428 | .893 | -.501 | -.556 | .567 | -.299 |
| Pz | .046 | .159 | 1.072 | .773 | .807 | .875 | -2.165* |
| P4 | .650 | .862 | .923 | 1.14 | 1.17 | .858 | -1.493 |
| P6 | .750 | .654 | .901 | .934 | 1.00 | .624 | -.515 |
| P5 | .060 | .061 | .976 | -.40 | -.557 | .898 | -1.605 |
| P3 | -.190 | -.194 | .816 | .041 | .013 | .714 | -1.195 |
| Cz | -.165 | .108 | 1.063 | .233 | .217 | .476 | -.896 |
| C3 | -.029 | -.053 | .686 | .059 | -.081 | .399 | 0.00 |
| C5 | .247 | .290 | .698 | .174 | .110 | .455 | -.448 |
| C4 | .575 | .624 | .863 | .831 | .873 | .535 | -1.307 |
| C6 | .542 | .475 | 1.129 | .440 | .987 | 1.69 | -.784 |
| T7 | .322 | .198 | 1.011 | -.404 | -.527 | .646 | -2.72** |
| T8 | .804 | .568 | .835 | .566 | .652 | .515 | -.597 |
| Fz | -.369 | -.146 | .958 | -.610 | -.693 | .479 | -1.381 |
| F3 | -.098 | -.084 | 1.064 | -.504 | -.551 | .454 | -1.717 |
| F7 | .568 | .472 | 1.110 | -.349 | -.422 | .549 | -3.02** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| F4 | .163 | -.020 | .965 | -.058 | -.059 | .439 | -.971 |
| F8 | .552 | .277 | 1.023 | .214 | .308 | .340 | -1.157 |
| FT8 | .679 | .606 | .861 | .28 | .299 | .398 | -1.692 |
| FT7 | .435 | .342 | .971 | -.114 | -.17 | .576 | -2.016* |
| FP1 | -.049 | .129 | 1.145 | -.91 | -.92 | 1.17 | -2.53** |
| FP2 | .239 | .078 | .999 | -.720 | -.778 | .571 | -3.06** |
| FC3 | .120 | .207 | .873 | -.181 | -.213 | .35 | -1.643 |
| FC4 | .171 | .185 | 1.019 | .487 | .419 | .506 | -1.083 |
| FCz | -.323 | -.121 | .945 | -.158 | -.11 | .460 | -.075 |
| CP5 | .164 | .046 | .822 | -.03 | -.123 | .598 | -.635 |
| TP7 | .154 | -.121 | 1.058 | -.350 | -.533 | .621 | 1.979* |
| TP8 | .688 | .624 | .834 | .803 | .690 | .507 | -.747 |
| CPz | -.085 | .051 | 1.226 | .75 | .69 | .715 | -2.203* |
| CP4 | .717 | .675 | .998 | .98 | 1.08 | .836 | -.933 |
| CP6 | .935 | .773 | .931 | .993 | 1.06 | .637 | -.373 |
| CP3 | .094 | -.059 | .779 | .418 | .212 | .642 | -1.195 |

Note: *: p<0.05; **: p<0.01.

In L1, N400 component (reduced shift in amplitudes) for semantically incorrect sentences was observed at Oz, P5, C3, T7, Fz, F3, F7, F4, FT8, FT7, FP1, FP2, FC3, CP5, and TP7 indicating that the distribution of N400 is broadly distributed over left hemisphere and few sites of right hemisphere. However, significant differences between semantically correct and semantically incorrect sentences were found at the centro-parietal regions, left frontal and temporal regions.

Table 43.

*Mean, Median and SD values of amplitude of N400 components for group II for semantically correct and semantically incorrect sentences in English.*

| **Electrode** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| O2 | -.276 | -.032 | .759 | .077 | .046 | .83 | -1.307 |
| O1 | -.869 | -.740 | .824 | -.358 | -.35 | .65 | -1.979 |
| Oz | -.553 | -.291 | .943 | -.19 | -.25 | .718 | -1.157 |
| Pz | -.355 | -.108 | .898 | -.18 | -.07 | 1.05 | -.373 |
| P4 | .048 | .157 | .800 | .318 | .10 | 1.03 | -.784 |
| P6 | -.069 | -.062 | .706 | .572 | .401 | .913 | -2.389* |
| P5 | -.49 | -.247 | .914 | -.443 | -.259 | .681 | -.075 |
| P3 | -.325 | -.075 | .954 | -.46 | -.307 | .79 | -.597 |
| Cz | -.09 | .032 | .84 | -.50 | -.338 | 1.10 | -1.269 |
| C3 | -.170 | -.034 | .958 | -.70 | -.719 | .88 | -1.829 |
| C5 | -.163 | -.089 | .722 | -.918 | -.786 | .804 | -3.09** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| C4 | .19 | .132 | .72 | .181 | .15 | 1.124 | -.187 |
| C6 | -.162 | .217 | 1.430 | .194 | .039 | .974 | -.373 |
| T7 | -.218 | -.237 | .420 | -.874 | -.753 | .728 | -3.13** |
| T8 | .272 | .31 | .519 | .517 | .49 | .706 | -1.083 |
| Fz | .253 | .137 | .920 | -1.68 | -1.33 | 1.486 | -3.84** |
| F3 | .002 | .031 | .680 | -1.45 | -1.55 | 1.26 | -3.50** |
| F7 | -.119 | -.05 | .597 | -1.23 | -1.31 | 1.23 | -2.72** |
| F4 | .029 | .080 | .686 | -.561 | -.787 | .904 | -2.427* |
| F8 | .017 | .06 | .72 | -.182 | -.368 | .813 | -1.493 |
| FT8 | .192 | .141 | .525 | .16 | .075 | .710 | -.523 |
| FT7 | -.196 | -.169 | .583 | -1.10 | -1.27 | 1.05 | -2.87** |
| FP1 | .11 | .23 | .993 | -.880 | -1.57 | 1.81 | -2.203* |
| FP2 | .128 | .088 | 1.06 | -1.20 | -1.58 | .95 | -3.39** |
| FC3 | -.18 | -.113 | .84 | -.898 | -.847 | .937 | -2.53** |
| FC4 | .111 | .102 | .670 | -.123 | -.011 | .998 | -1.008 |
| FCz | -.047 | .027 | .87 | -.84 | -.565 | 1.16 | -2.464* |
| CP5 | -.278 | -.252 | .769 | -.595 | -.426 | .698 | -1.232 |
| TP7 | -.24 | -.153 | .46 | -.71 | -.63 | .66 | -2.53** |
| TP8 | .023 | -.033 | .51 | .67 | .54 | .81 | -2.76** |
| CPz | -.32 | -.15 | .96 | -.32 | -.40 | 1.07 | -.075 |
| CP4 | .100 | .174 | .708 | .19 | .23 | 1.06 | -.523 |
| CP6 | .04 | .08 | .716 | .46 | .35 | .974 | -1.867 |
| CP3 | -.22 | -.148 | 1.01 | -.46 | -.37 | .802 | -.821 |

Note: *: $p<0.05$; **: $p<0.01$.

In L2, N400 component for semantically incorrect sentences was observed at P4, P5, P3, Cz, C3, C5, T7, Fz, F3, F7, F4, F8, FT7, FP1, FP2, FC3, FC4, FCz, CP5, TP7, CPz, and CP3. However, significant differences between amplitudes of semantically correct and semantically incorrect sentences were observed at right parietal, temporal and frontal regions of both left and right hemispheres. These results indicate that the semantic aspects of language are processed by left hemisphere in L1. While in L2, bilateral hemispheric activation is seen in typical bilinguals. Figure 10 and 11 represent the grand average waveforms of N400 components of group II in Kannada and English respectively.

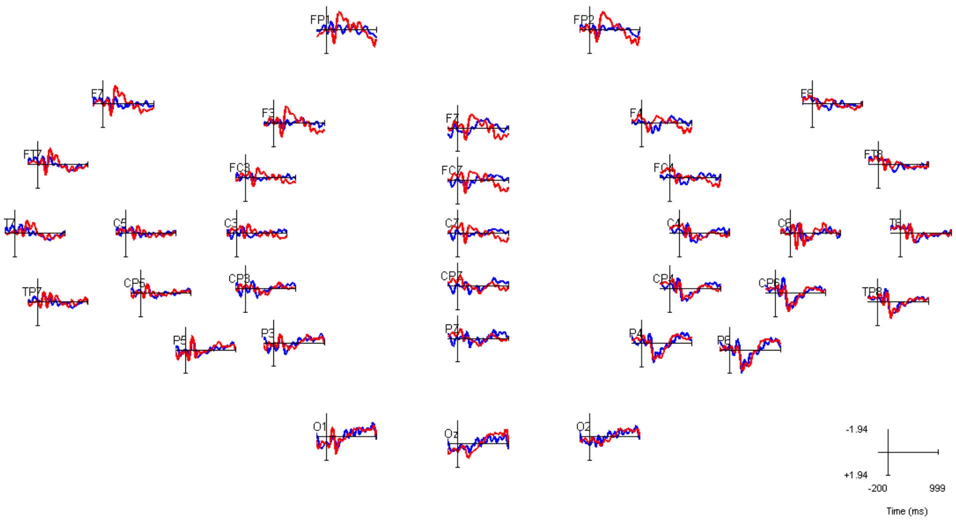


*Figure 10*. Grand average waveforms of 34 electrodes of Group II for semantically correct and semantically incorrect sentences in Kannada.

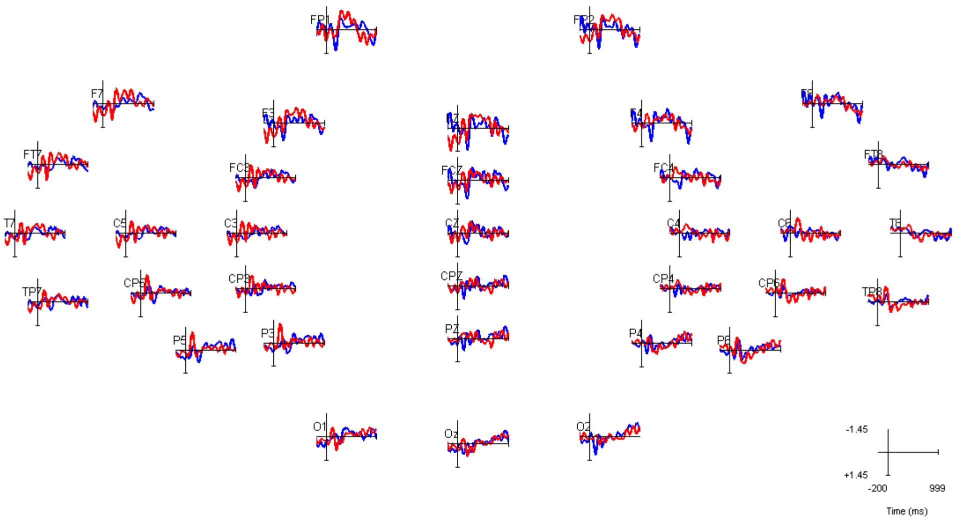

*Figure 11*. Grand average waveforms of 34 electrodes of Group II for semantically correct and semantically incorrect sentences in English.

*4.4.1.1. Between electrode comparison for 34 electrodes for Group II of semantically correct and semantically incorrect sentences in Kannada.*

Friedman test was conducted to evaluate the differences in amplitudes of 34 electrodes for semantically correct sentences in Kannada and results revealed significant difference between the electrodes for group II ($\chi^2$ (33) = 163.23, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group II for each type of sentence. Results of pair-wise comparisons between electrodes for group II for correct sentences in Kannada are given in Table 44.

Table 44.

*Pair-wise comparisons of 34 electrodes for correct sentences in Kannada for group II.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | - | - | - | + | + | + | - | - | - | + | + | + | + | + | - | - | + | - | + | + | + | - | + | + | - | - | + | - | + | - | + | + | - |
| O1 | | | - | + | + | + | + | + | - | + | + | + | + | + | + | - | + | + | + | + | + | + | + | + | + | + | - | + | + | + | - | + | + | + |
| Oz | | | | - | + | + | + | + | - | + | + | + | + | + | + | - | - | + | + | + | + | + | - | - | + | + | - | + | + | + | - | + | + | + |
| Pz | | | | | + | + | - | - | - | - | - | + | - | - | + | - | - | - | - | - | + | - | - | - | - | - | + | - | - | - | - | + | + | - |
| P4 | | | | | | - | + | + | + | + | + | - | - | - | - | + | + | - | - | - | - | + | - | + | - | + | - | + | - | + | - | - | + | + |
| P6 | | | | | | | + | + | + | + | + | - | - | - | - | + | + | - | - | - | - | - | + | - | - | - | + | + | + | - | + | - | - | + |
| P5 | | | | | | | | + | - | - | - | - | - | - | + | - | - | + | - | - | + | + | - | - | - | - | - | - | - | + | - | + | + | - |
| P3 | | | | | | | | | - | - | + | + | + | + | + | - | - | + | - | - | + | + | - | - | - | - | - | + | - | + | - | + | + | + |
| Cz | | | | | | | | | | - | - | + | + | - | + | - | - | + | - | + | + | - | - | - | - | + | - | - | - | + | - | + | + | - |
| C3 | | | | | | | | | | | - | + | + | - | + | - | - | - | - | + | + | - | - | - | - | - | - | - | - | + | - | + | + | - |
| C5 | | | | | | | | | | | | - | - | - | + | + | - | - | - | - | + | - | - | - | - | - | + | - | - | + | - | + | + | - |
| C4 | | | | | | | | | | | | | - | - | - | + | + | - | + | - | - | - | + | - | + | + | + | - | - | - | + | - | + | + |
| C6 | | | | | | | | | | | | | | - | - | + | + | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | + | - |
| T7 | | | | | | | | | | | | | | | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - |
| T8 | | | | | | | | | | | | | | | | + | + | - | + | - | - | - | + | + | + | + | + | + | + | - | + | - | - | + |
| Fz | | | | | | | | | | | | | | | | | - | + | + | + | + | + | - | + | + | + | - | - | - | + | - | + | + | - |
| F3 | | | | | | | | | | | | | | | | | | + | - | + | + | - | - | - | - | + | - | - | - | + | - | + | + | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | + | - | - | - | + | - | + | - | - | - | - | + |
| F4 | | | | | | | | | | | | | | | | | | | | + | + | - | - | - | - | - | + | - | - | - | - | + | + | - |

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| F8 | | | | | | | | | | | | | | | | | | | | | - | - | + | + | - | - | + | - | - | - | - | - | - | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | + | + | + | + | + | + | + | - | + | - | - | + |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | + | - | + | - | - | - | + | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | + | - | + | + | - |
| FP2 | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | + | + | - |
| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | | - | + | - | - | - | - | + | + | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | - | - | + | + | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | + | - | + | + | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | + | - | + | + | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | + | + | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | + | + |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | + | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | + |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: ‘+’: p<0.001; ‘-‘: p>0.001.

Friedman test results revealed significant difference between the electrodes for Group II for semantically incorrect sentences ($\chi^2$ (33) = 337.38, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group II for semantically incorrect sentences. Results of pair-wise comparisons between electrodes for group II for semantically incorrect sentences in Kannada are given in Table 45.

Table 45.

*Pair-wise comparisons of 34 electrodes for semantically incorrect sentences in Kannada for group II.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | + | - | + | + | + | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | + | + | + | + | + |
| O1 | | | + | + | + | - | + | + | + | + | + | + | - | + | - | - | - | - | - | + | + | - | - | - | - | + | - | + | - | + | + | + | + | + |
| Oz | | | | + | + | - | + | + | + | + | - | - | + | - | - | - | - | - | - | + | - | - | - | - | - | + | - | - | - | + | + | + | + | + |
| Pz | | | | | - | + | - | - | + | + | - | - | + | - | + | + | + | + | - | - | + | + | + | + | - | + | + | + | - | - | - | - | - | - |
| P4 | | | | | | - | + | + | + | + | + | - | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | - | + | - | - | + |
| P6 | | | | | | | + | + | + | + | + | - | - | + | + | + | + | + | + | + | + | + | + | + | + | - | + | + | + | - | - | - | + | + |
| P5 | | | | | | | | + | - | - | + | - | - | + | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | + | + | + | + | + |
| P3 | | | | | | | | | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | + | + | - | - |
| Cz | | | | | | | | | | - | - | + | - | - | - | + | + | + | - | - | - | - | + | + | + | - | + | - | - | + | + | + | - | - |
| C3 | | | | | | | | | | | - | + | - | + | + | + | + | + | - | - | - | - | + | + | + | + | - | - | + | + | + | + | + | + |
| C5 | | | | | | | | | | | | + | - | + | - | + | + | + | - | - | - | - | + | + | + | - | - | - | + | + | + | + | + | - |
| C4 | | | | | | | | | | | | | - | + | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | - | - | - | - | - |
| C6 | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - |
| T7 | | | | | | | | | | | | | | | + | - | - | - | + | + | + | + | - | - | - | + | - | + | - | + | + | + | + | + |
| T8 | | | | | | | | | | | | | | | | + | + | + | - | + | + | + | + | + | - | + | + | + | - | - | + | + | - | - |
| Fz | | | | | | | | | | | | | | | | | - | + | + | + | - | - | + | + | + | - | - | + | + | + | + | + | + | + |
| F3 | | | | | | | | | | | | | | | | | | - | + | + | - | - | - | + | + | + | - | - | + | + | + | + | + | + |
| F7 | | | | | | | | | | | | | | | | | | | - | + | + | - | + | - | + | - | - | - | + | + | + | + | + | + |
| F4 | | | | | | | | | | | | | | | | | | | | - | + | + | - | + | - | - | - | - | - | + | + | + | + | - |
| F8 | | | | | | | | | | | | | | | | | | | | | - | - | + | + | + | - | - | - | - | + | + | + | + | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | + | + | - | - | - | - | + | - | + | + | - | + |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | + | - | + | - | - | - | + | + | + | + | + | + |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | + | - | - | - | + | + | + | + | + | + |
| FP | | | | | | | | | | | | | | | | | | | | | | | | | + | + | + | - | + | + | + | + | + | + |

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| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | + | + | + | + | + | + |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | + | + | - | - | - | + | - | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | - | + | + | + | + | + | + |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | + | + | + | + | + |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | + | + | + | + |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: p<0.001; -: p>0.001.

*4.4.1.2. Between electrode comparison for 34 electrodes for Group II of semantically correct and semantically incorrect sentences in English.*

Friedman test was conducted to evaluate the differences in amplitudes of 34 electrodes for semantically correct sentences in English and results revealed significant difference between the electrodes for group II ($\chi^2$ (33) = 96.213, $p < .01$). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group II for each type of sentence. Results of pair-wise comparisons between electrodes for group II for correct sentences in English are given in Table 46.

Table 46.

*Pair-wise comparisons of 34 electrodes for semantically correct sentences in English for group II.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | + | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - |
| O1 | | | - | + | + | + | - | + | + | - | - | + | - | - | + | + | + | - | - | - | + | - | - | - | - | + | + | - | + | + | - | + | + | + |
| Oz | | | | - | + | + | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - |
| Pz | | | | | + | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - |
| P4 | | | | | | - | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - |
| P6 | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P5 | | | | | | | | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | + | - | - |
| P3 | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cz | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C3 | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C5 | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C4 | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | + | - | - | - |
| C6 | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T7 | | | | | | | | | | | | | | | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - |
| Fz | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F3 | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F4 | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F8 | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - |
| FP | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - |

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| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | + | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: $p<0.001$; -: $p>0.001$.

Friedman test results revealed significant difference between the electrodes for Group II for semantically incorrect sentences in English ($\chi^2$ (33) = 354.98, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group II for semantically incorrect sentences and results are given in Table 47.

Table 47.

*Pair-wise comparisons of 34 electrodes for semantically incorrect sentences in English for group II.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | + | - | - | - | - | + | + | - | + | + | - | - | + | - | + | + | + | - | - | - | + | - | + | + | - | + | + | + | - | - | - | - | + |
| O1 | | | - | - | + | + | - | - | - | - | + | - | - | + | + | + | + | + | - | - | - | - | - | + | - | - | - | - | + | + | - | - | + | - |
| Oz | | | | - | - | + | - | - | - | - | + | - | - | + | - | + | + | + | - | - | - | - | - | + | + | - | - | - | + | + | - | - | - | - |
| Pz | | | | | + | + | - | - | - | + | + | - | - | + | - | + | + | + | - | - | - | + | - | + | + | - | + | - | - | + | - | + | + | - |
| P4 | | | | | | - | + | + | + | + | + | - | - | + | - | + | + | + | + | - | - | + | - | + | + | - | + | + | + | - | + | - | - | + |
| P6 | | | | | | | + | + | + | + | + | - | + | + | - | + | + | + | + | + | - | + | - | + | + | + | + | + | + | - | + | - | - | + |
| P5 | | | | | | | | - | - | - | + | - | - | - | + | + | + | - | - | - | - | - | - | + | - | - | - | - | - | + | - | + | + | - |
| P3 | | | | | | | | | - | - | + | + | - | - | + | + | + | + | - | - | + | - | - | + | - | - | - | - | - | + | - | + | + | - |
| Cz | | | | | | | | | | - | - | + | - | - | + | + | + | + | - | - | + | - | - | + | + | + | + | - | - | + | - | + | + | - |
| C3 | | | | | | | | | | | - | + | + | - | + | + | + | - | - | + | + | - | - | + | - | + | - | - | - | + | + | + | + | - |
| C5 | | | | | | | | | | | | + | + | - | + | + | - | - | - | + | + | - | - | - | - | + | - | - | - | + | + | + | + | + |
| C4 | | | | | | | | | | | | | - | + | - | + | + | + | + | - | - | + | - | + | + | + | + | + | - | - | + | - | - | + |
| C6 | | | | | | | | | | | | | | + | - | + | + | + | + | - | - | + | - | + | + | - | + | + | + | + | - | - | + | + |
| T7 | | | | | | | | | | | | | | | + | - | - | - | - | + | + | - | - | - | - | + | - | - | - | + | - | + | + | - |
| T8 | | | | | | | | | | | | | | | | + | + | + | + | + | + | + | - | + | + | + | + | + | - | + | - | - | - | + |
| Fz | | | | | | | | | | | | | | | | | - | - | + | + | + | - | - | - | + | + | + | + | - | + | + | + | + | + |
| F3 | | | | | | | | | | | | | | | | | | - | + | + | + | - | - | - | + | + | + | - | - | + | + | + | + | + |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | + | - | - | - | + | + | + | + | - | + | + | - |
| F4 | | | | | | | | | | | | | | | | | | | | + | + | + | - | + | + | + | - | - | - | + | - | + | + | - |
| F8 | | | | | | | | | | | | | | | | | | | | | + | + | - | + | + | - | + | - | - | + | - | - | + | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | + | - | + | + | - | + | + | + | + | - | - | - | + |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | + | - | - | - | + | + | + | + | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - |
| FP | | | | | | | | | | | | | | | | | | | | | | | | | - | + | - | - | - | + | + | + | + | + |

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| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | - | + | + | + | + | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | + | - | - | + | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | + | + | + | + | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | + | - | + | + | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | + | + | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | + |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | + | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | + |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: p<0.001; -: p>0.001.

*4.4.1.3. Comparison of amplitudes between Kannada and English for semantically correct and semantically incorrect sentences of Group II.*

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of 34 electrodes between Kannada and English for semantically correct and semantically incorrect sentences of Group II. /Z/ values group II for semantically correct sentences and semantically incorrect sentences are given in Table 48.

Table 48.

*Significant differences between Kannada and English for semantically correct and semantically incorrect sentences group II.*

| Electrode | Semantically Correct sentences | /Z/ | Semantically incorrect sentences | /Z/ |
|---|---|---|---|---|
| O2 | Kan Vs Eng | -.149 | Kan Vs Eng | -1.120 |
| O1 | Kan Vs Eng | -.821 | Kan Vs Eng | -1.419 |
| Oz | Kan Vs Eng | -.224 | Kan Vs Eng | -1.157 |
| Pz | Kan Vs Eng | -1.008 | Kan Vs Eng | -2.80** |
| P4 | Kan Vs Eng | -1.493 | Kan Vs Eng | -2.501* |
| P6 | Kan Vs Eng | -2.46* | Kan Vs Eng | -1.755 |
| P5 | Kan Vs Eng | -1.941 | Kan Vs Eng | -.001 |
| P3 | Kan Vs Eng | -.635 | Kan Vs Eng | -1.829 |
| Cz | Kan Vs Eng | -.149 | Kan Vs Eng | -2.539* |
| C3 | Kan Vs Eng | -.187 | Kan Vs Eng | -2.83** |
| C5 | Kan Vs Eng | -1.605 | Kan Vs Eng | -3.58** |
| C4 | Kan Vs Eng | -.933 | Kan Vs Eng | -2.203* |
| C6 | Kan Vs Eng | -1.008 | Kan Vs Eng | -.859 |
| T7 | Kan Vs Eng | -2.24* | Kan Vs Eng | -1.867 |
| T8 | Kan Vs Eng | -.037 | Kan Vs Eng | -1.493 |
| Fz | Kan Vs Eng | -1.493 | Kan Vs Eng | -2.72** |
| F3 | Kan Vs Eng | -.261 | Kan Vs Eng | -2.57* |
| F7 | Kan Vs Eng | -2.24* | Kan Vs Eng | -2.613** |
| F4 | Kan Vs Eng | -.263 | Kan Vs Eng | -2.16* |
| F8 | Kan Vs Eng | -1.755 | Kan Vs Eng | -2.091* |
| FT8 | Kan Vs Eng | -1.867 | Kan Vs Eng | -.560 |
| FT7 | Kan Vs Eng | -2.27* | Kan Vs Eng | -3.09** |
| FP1 | Kan Vs Eng | -.037 | Kan Vs Eng | -.075 |
| FP2 | Kan Vs Eng | -.672 | Kan Vs Eng | -1.755 |
| FC3 | Kan Vs Eng | -.859 | Kan Vs Eng | -2.76** |
| FC4 | Kan Vs Eng | -.224 | Kan Vs Eng | -2.352* |
| FCz | Kan Vs Eng | -.655 | Kan Vs Eng | -2.301* |
| CP5 | Kan Vs Eng | -1.86 | Kan Vs Eng | -2.128* |
| TP7 | Kan Vs Eng | -1.56 | Kan Vs Eng | -1.307 |
| TP8 | Kan Vs Eng | -2.4* | Kan Vs Eng | -.821 |

| | | | | |
|---|---|---|---|---|
| CPz | Kan Vs Eng | -.635 | Kan Vs Eng | -2.98** |
| CP4 | Kan Vs Eng | -1.60 | Kan Vs Eng | -2.352* |
| CP6 | Kan Vs Eng | -2.4* | Kan Vs Eng | -2.016 |
| CP3 | Kan Vs Eng | -1.00 | Kan Vs Eng | -2.91** |

Note: *: $p<0.05$; **: $p<0.01$.

Comparisons between L1 and L2 have shown differences between processing of L1 and L2 at few electrode sites majorly in left hemisphere for correct sentences and for incorrect sentences differences were found in both right and left hemispheres indicating few differences in processing of each type of sentence in L1 and L2.

***4.4.2. Scalp region-wise analysis of N400 effect in group II in Kannada and English.***

The ERP responses of all eight scalp regions were analyzed and the mean values of responses in the duration of 300-500ms were measured by using independent component analysis of Matlab software for measuring N400 effect in group II. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of eight scalp regions for semantically correct and semantically incorrect sentences in Kannada and English for group II. Table 49 and 50 represent the mean, median and standard deviations and /Z/ values of N400 component for group II for correct sentences and semantically incorrect sentences in Kannada and English respectively.

Table 49.

*Mean, Median and SD values of amplitude of N400 components of eight scalp regions for group II for semantically correct and semantically incorrect sentences in Kannada.*

| Hemispheric region | Amplitudes for Semantically correct sentences | | | Amplitudes for Semantically incorrect sentences | | | /Z/ |
|---|---|---|---|---|---|---|---|
| | Mean (in µv) | Median | SD (in µv) | Mean (in µv) | Median | SD (in µv) | |
| Left anterior | .189 | .163 | .793 | -.432 | -.495 | .562 | -.635 |
| Right anterior | .361 | .262 | .880 | .042 | .051 | .341 | -1.195 |
| Left central | .109 | .064 | .624 | .116 | .009 | .409 | -1.381 |
| Right central | .559 | .621 | .952 | .635 | .903 | .968 | -.971 |
| Left centro-parietal | .129 | .105 | .741 | .143 | -.024 | .481 | -.896 |
| Right centro-parietal | .826 | .693 | .914 | .989 | 1.07 | .723 | -.187 |
| Left posterior | -.064 | -.126 | .861 | -.182 | -.351 | .794 | -.166 |
| Right posterior | .750 | .763 | .977 | 1.03 | 1.175 | .733 | -.154 |

Note: *: p<0.05; **: p<0.01.

Negative activation (N400) is observed at left posterior and left central scalp regions during processing of semantically correct sentences in L1 indicating typical pattern of N400 localized at centro-parietal regions of left hemisphere. During processing of semantically incorrect sentences, typical individuals showed typical negative amplitudes than that for correct sentences at left posterior regions.

Table 50.

*Mean, Median and SD values of amplitude of N400 components of eight scalp regions for group II for semantically correct and semantically incorrect sentences in English.*

| Hemispheric region | Amplitudes for Semantically correct sentences | | | Amplitudes for Semantically incorrect sentences | | | /Z/ |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| Left anterior | -.077 | -.038 | .644 | -1.11 | -1.32 | 1.19 | -3.024** |
| Right anterior | .095 | .102 | .650 | -.382 | -.630 | .806 | -1.568 |
| Left central | -.166 | .003 | .833 | -.761 | -.77 | .719 | -3.696** |
| Right central | .559 | .621 | .935 | .018 | .284 | .879 | -1.531 |
| Left centro-parietal | -.252 | -.197 | .886 | -.252 | -.197 | .717 | -3.659** |
| Right centro-parietal | .072 | .242 | .695 | .281 | .261 | .904 | -.971 |
| Left posterior | -.409 | -.161 | .928 | -.455 | -.278 | .727 | -3.547** |
| Right posterior | -.010 | .003 | .744 | .395 | .267 | .880 | -1.904 |

Note: *: p<0.05; **: p<0.01.

In L2, scalp region analysis revealed bilateral activation majorly at left anterior, left central, left centro-parietal and right posterior regions for both correct and semantically incorrect sentences. Pair-wise comparisons of amplitudes of correct and semantically incorrect sentences in L1 revealed significant differences only at left anterior region while significant differences were observed at left anterior, right anterior, left central and right posterior regions for L2.

*4.4.2.1. Between scalp region comparison for eight regions for Group II of semantically correct and semantically incorrect sentences in Kannada.*

Friedman test was conducted to evaluate the differences in amplitudes of eight scalp regions for semantically correct sentences in Kannada and results revealed significant difference between the electrodes for group II ($\chi^2$ (7) = 20.633, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between scalp regions in group II for semantically correct sentences. Results of pair-wise comparisons between scalp regions for group II for correct sentences in Kannada are given in Table 51.

Table 51.

*Pair-wise comparisons of eight scalp regions for correct sentences in Kannada for group II.*

| Scalp region | LA | RA | LC | RC | LCP | RCP | LP | RP |
|---|---|---|---|---|---|---|---|---|
| LA | | -.821 | -.635 | -1.755 | -.373 | -2.80** | -1.157 | -2.427* |
| RA | | | -1.157 | -1.456 | -1.008 | -2.352* | -1.419 | -1.195 |
| LC | | | | -2.053* | -.224 | -2.87** | -1.269 | -2.501* |
| RC | | | | | -1.867 | -2.352* | -2.165* | -1.008 |
| LCP | | | | | | -3.02** | -2.57** | -2.75** |
| RCP | | | | | | | -3.13** | -.971 |
| LP | | | | | | | | -2.98** |
| RP | | | | | | | | |

**: p<0.01. *: p<0.05.

Friedman test results revealed significant difference between the electrodes for Group II for semantically incorrect sentences ($\chi^2$ (7) = 59.70, $p < .01$). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between scalp regions in group II for semantically incorrect sentences in Kannada. Results of pair-wise comparisons between scalp regions for group II for semantically incorrect sentences in Kannada are given in Table 52.

Table 52.

*Pair-wise comparisons of eight scalp regions for incorrect sentences in Kannada for group II.*

| Scalp region | LA | RA | LC | RC | LCP | RCP | LP | RP |
|---|---|---|---|---|---|---|---|---|
| LA | | -3.39** | -3.69** | -3.47** | -3.21** | -3.73** | -1.12 | -3.77** |
| RA | | | -.709 | -2.50* | -.933 | -3.80** | -1.15 | -3.77** |
| LC | | | | -2.61** | -.075 | -3.54** | -1.68 | -3.73** |
| RC | | | | | -2.31* | -1.90 | -2.61** | -2.27* |
| LCP | | | | | | -2.46* | -3.47** | -3.57** |
| RCP | | | | | | | -3.39** | -1.26 |
| LP | | | | | | | | -3.51** |
| RP | | | | | | | | |

**: p<0.01. *: p<0.05.

*4.4.2.2. Between scalp region comparison for eight regions for Group II of semantically correct and semantically incorrect sentences in English.*

Friedman test was conducted to evaluate the differences in amplitudes of eight scalp regions for semantically correct sentences in English and results revealed significant difference between the electrodes for group II ($\chi^2$ (7) = 15.50, $p < .05$). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between scalp regions in group II for semantically correct sentences. Results of pair-wise comparisons between scalp regions for group II for correct sentences in English are given in Table 53.

Table 53.

*Pair-wise comparisons of eight scalp regions for correct sentences in English for group II.*

| Scalp region | LA | RA | LC | RC | LCP | RCP | LP | RP |
|---|---|---|---|---|---|---|---|---|
| LA | | -1.23 | -.635 | -.896 | -.933 | -.93 | -1.419 | .373 |
| RA | | | -.90 | -.49 | -1.12 | -.112 | -1.53 | -.336 |
| LC | | | | -1.157 | -1.34 | -1.97* | -1.90 | -1.16 |
| RC | | | | | -1.31 | -1.08 | -1.68 | -1.04 |
| LCP | | | | | | -2.46* | -2.05* | -2.13* |
| RCP | | | | | | | -2.95** | -1.42 |
| LP | | | | | | | | -2.80** |
| RP | | | | | | | | |

**: p<0.01. *: p<0.05.

Friedman test results revealed significant difference between the scalp regions for Group II for semantically incorrect sentences in English ($\chi^2$ (7) = 82.817, $p < .01$). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between scalp regions in group II for semantically incorrect sentences. Results of pair-wise comparisons between scalp regions for group II for semantically incorrect sentences in English are given in Table 54.

Table 54.

*Pair-wise comparisons of eight scalp regions for semantically incorrect sentences in English for group II.*

| Scalp region | LA | RA | LC | RC | LCP | RCP | LP | RP |
|---|---|---|---|---|---|---|---|---|
| LA | | -3.51** | -2.13* | -3.43** | -2.43* | -3.81** | -2.69** | -3.77** |
| RA | | | -3.29** | -3.17** | -1.04 | -3.77** | -.709 | -3.81** |
| LC | | | | -3.81** | -2.389* | -3.92** | -2.501* | -3.92** |
| RC | | | | | -3.47** | -2.13* | -3.06** | -2.46* |
| LCP | | | | | | -3.56** | -1.42 | -3.92** |
| RCP | | | | | | | -3.55** | -1.49 |
| LP | | | | | | | | -3.88** |
| RP | | | | | | | | |

**: p<0.01. *: p<0.05.

*4.4.2.3. Comparison of amplitudes between Kannada and English for semantically correct and semantically incorrect sentences of Group II across eight scalp regions.*

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of eight scalp regions between Kannada and English for semantically correct and semantically incorrect sentences for group II. /Z/ values group II are given in Table 55 for semantically correct and semantically incorrect sentences.

Table 55.

*Significant differences between Kannada and English for correct and incorrect sentences in group II.*

| **Scalp region** | **Correct sentences** | **/Z/** | **Semantically incorrect sentences** | **/Z/** |
|---|---|---|---|---|
| Left anterior | Kan Vs Eng | -1.045 | Kan Vs Eng | -2.315* |
| Right anterior | Kan Vs Eng | -1.083 | Kan Vs Eng | -1.979* |
| Left central | Kan Vs Eng | -.859 | Kan Vs Eng | -3.285** |
| Right central | Kan Vs Eng | -1.18 | Kan Vs Eng | -1.717 |
| Left centro-parietal | Kan Vs Eng | -1.31 | Kan Vs Eng | -2.80** |
| Right centro-parietal | Kan Vs Eng | -1.942 | Kan Vs Eng | -2.464** |
| Left posterior | Kan Vs Eng | -1.27 | Kan Vs Eng | -.821 |
| Right posterior | Kan Vs Eng | -1.755 | Kan Vs Eng | -2.389* |

Note: *: p<0.05; **: p<0.01.

Comparison of amplitudes of L1 and L2 at eight scalp regions showed no significant differences between processing of L1 and L2 in correct sentences and showed significant differences between L1 and L2 at left anterior, right anterior, left central, left centro-parietal, right centro-parietal and at right posterior regions (indicating differential processing of L1 and L2) for only semantically incorrect sentences but not for semantically correct sentences.

### 4.4.3. Hemispheric activation *analysis of N400 effect in group II in Kannada and English.*

The ERP responses of all three hemispheric regions were analyzed and the mean values of responses in the duration of 300-500ms were measured by using independent component analysis of Matlab software for measuring N400 effect in group II. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of three hemispheric regions for semantically correct and semantically incorrect sentences in Kannada and English for group II. Table 56 and 57 represent the mean, median and standard deviations and /Z/ values of N400 component for group II for correct sentences and semantically incorrect sentences in Kannada and English respectively.

Table 56.

*Mean, Median and SD values of amplitude of N400 components of three hemispheric regions for group II for semantically correct and semantically incorrect sentences in Kannada.*

| Hemispheric region | Amplitudes for Semantically correct sentences | | | Amplitudes for Semantically incorrect sentences | | | /Z/ |
|---|---|---|---|---|---|---|---|
| | Mean (in µv) | Median | SD (in µv) | Mean (in µv) | Median | SD (in µv) | |
| Right hemisphere | .297 | .598 | .232 | .193 | .519 | .105 | -1.195 |
| Central region | -.009 | .665 | .013 | -.035 | .702 | -.076 | -.037 |
| Left hemisphere | -.091 | .853 | .173 | -.026 | .752 | -.004 | -.821 |

Note: *: p<0.05; **: p<0.01.

Table 57.

*Mean, Median and SD values of amplitude of N400 components of three hemispheric regions for group II for semantically correct and semantically incorrect sentences in English.*

| Hemispheric region | Amplitudes for Semantically correct sentences | | | Amplitudes for Semantically incorrect sentences | | | /Z/ |
|---|---|---|---|---|---|---|---|
| | Mean (in µv) | Median | SD (in µv) | Mean (in µv) | Median | SD (in µv) | |
| Right hemisphere | .820 | .585 | .897 | .519 | .580 | .584 | -1.680 |
| Central region | .528 | .735 | .444 | -.261 | .720 | -.210 | -3.136** |
| Left hemisphere | .491 | .781 | .720 | -.699 | .714 | -.649 | -3.920** |

Note: *: p<0.05; **: p<0.01.

Results of hemispheric activation analysis revealed greater negative activation seen for both correct and semantically incorrect sentences in left hemisphere followed by central and right hemisphere in L1 & L2 indicating greater involvement of left hemisphere in processing of semantic information in both L1 and L2. However, the differences in amplitudes between semantically correct and semantically incorrect sentences are not statistically significant in L1. In L2, statistically significant difference was observed between semantically correct and semantically incorrect sentences only in left hemisphere but no significant differences were found in right hemisphere and central regions.

*4.4.3.1. Comparison of three hemispheric regions of group II for semantically correct sentences in Kannada.*

Friedman test results revealed significant difference between three hemispheric regions for Group II ($\chi^2$ (2) = 13.30, $p < .01$) for semantically correct sentences. Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between hemispheric regions in group II for each type of sentence. Results of Wilcoxon tests in Kannada are given in Table 58 for group II.

Table 58.

*Pair-wise comparisons of three hemispheric regions for correct sentences in Kannada for group II.*

| | Right hemisphere | Central region | Left hemisphere |
|---|---|---|---|
| Right hemisphere | | -3.584** | -2.576** |
| Central region | | | -1.083 |
| Left hemisphere | | | |

**: p<0.01.

Significant difference was also found between hemispheric regions for semantically incorrect sentences in group II ($\chi^2$ (2) = 18.10, $p < .01$). Wilcoxon post hoc test results for semantically incorrect sentences of group II are given in Table 59.

Table 59.

*Pair-wise comparisons of three hemispheric regions for correct sentences in Kannada for group II.*

| | Right hemisphere | Central region | Left hemisphere |
|---|---|---|---|
| Right hemisphere | | -3.733** | -3.472** |
| Central region | | | -2.539* |
| Left hemisphere | | | |

**: p<0.01. *: p<0.05.

*4.4.3.2. Comparison of three hemispheric regions of group II for semantically correct sentences in English.*

Friedman test results revealed significant difference between three hemispheric regions for Group II ($\chi^2$ (2) = 17.50, $p$ < .01) for semantically correct sentences in English. Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between hemispheric regions in group II for each type of sentence. Results of Wilcoxon tests in English are given in Table 60 for group II.

Table 60.

*Pair-wise comparisons of three hemispheric regions for semantically correct sentences in English for group II.*

| | Right hemisphere | Central region | Left hemisphere |
|---|---|---|---|
| Right hemisphere | | -1.307 | -2.352* |
| Central region | | | -1.643 |
| Left hemisphere | | | |

*: p<0.05.

Results of Friedman test also revealed significant differences between three hemispheric regions for semantically incorrect sentences for Group II ($\chi^2$ (2) = 28.30, $p$ < .01). Wilcoxon post hoc test results are given in Table 61 for semantically incorrect sentences in English for Group II.

Table 61.

*Pair-wise comparisons of three hemispheric regions for incorrect sentences in English for group II.*

| | Right hemisphere | Central region | Left hemisphere |
|---|---|---|---|
| Right hemisphere | | -3.920** | -3.883** |
| Central region | | | -1.605 |
| Left hemisphere | | | |

**: p<0.01.

*4.4.3.3. Comparison of amplitudes between Kannada and English for semantically correct and semantically incorrect sentences of Group II across three hemispheric regions.*

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of three hemispheric regions between Kannada and English for semantically correct and semantically incorrect sentences for group II. /Z/ values group II are given in Table 62 for semantically correct and semantically incorrect sentences.

Table 62.

*Significant differences between Kannada and English for correct and incorrect sentences in group II.*

| | Correct sentences | /Z/ | Semantically incorrect sentences | /Z/ |
|---|---|---|---|---|
| Right hemisphere | Kan Vs Eng | -1.157 | Kan Vs Eng | -2.277* |
| Central hemisphere | Kan Vs Eng | -.187 | Kan Vs Eng | -1.195 |
| Left hemisphere | Kan Vs Eng | -1.120 | Kan Vs Eng | -2.389* |

Note: *:$p<0.05$.

Comparisons of hemispheric activation levels between L1 and L2 revealed significant differences in right hemisphere for semantically incorrect sentences with higher activation levels in right hemisphere for L2 compared to that of L1. These results also revealed involvement of both the hemispheres in processing of semantic information in L2.

***General discussion on semantic processing in typical bilinguals***

The results of the present study reported involvement of left hemisphere regions for processing semantic incongruities in L1 and bilateral activation for processing semantic incongruities in L2. These results are supported by the earlier studies carried out on semantic processing at sentence level in bilinguals by Ardal et al (1990) who reported reduced amplitudes of N400 and increased latency for L2 in bilinguals and Weber-Fox and Neville (1996) who reported maximal amplitudes in posterior regions in both hemispheres with slightly large effect on right hemisphere for L2 for semantic incongruities. They have also reported the amplitude levels and latency of N400 is directly related to the proficiency level of each of the language in bilinguals. Similar type of results were reported by Hahne and Friederici (2001) who reported presence of N400 effect between 400-700ms in bilinguals over posterior sites and also over anterior and central regions of right hemisphere.

However, the results of the present study found no correlation to the studies by Kotz (2001), De Brujin, et al (2001) who reported no significant differences between L1 and L2 on amplitudes and latencies in lexical processing. This may be due to the fact that the lexical processing is different to that sentence processing which involves extra linguistic, contextual cues which may result in differential processing of sentences. Few studies were also carried out by Hahne (2001), Thierry and Wu (2007) to study the difference in semantic processing between monolinguals and bilinguals who reported significant differences in bilinguals with increased latency and reduced amplitudes compared to monolinguals.

Studies by Proverbio, et al (2002), Moreno and Kutas (2005), Guo, et al, (2009), Midgley, et al (2009), and Braunstein, et al (2012) have majorly focused on studying the topographical distribution of N400 for semantically incongruent stimuli and reported differential cortical activation for L1 and L2 in bilinguals at both word and sentence levels. Proverbio, et al (2002) have reported presence of early negative potentials across occipito-temporal regions in Italian-Slovenian bilinguals indicating differential processing of orthography information in two languages by bilinguals. The study also reported semantic violations in both L1 and L2 elicited N400 responses with greater activation over left hemisphere than right hemisphere. However, the present results revealed that the semantic violations in L1 elicited N400 responses with greater activation over left hemisphere and semantic violations in L2 elicited bilateral cortical activation. These results may be due to differences in language structures of Kannada and English compared to that of Italian and Slovenian.

Study by Moreno and Kutas (2005) have also reported higher centro-parietal negativity between 200-600 ms in both L1 and L2 for semantically violated sentences in semantic judgment task. They have also reported that the factors such as late exposure, dominant language, and proficiency levels have an effect on N400 latency and amplitudes in bilinguals. Guo et al (2009) have reported presence of N400 component for syntactically violated sentences in L2 indicating that the bilinguals use semantic information to process syntactic structures, specifically for verb sub-categorization violations in L2. Midgley, et al, (2009) also found that N400 latency and amplitudes were similar in both L1 and L2 for semantic violations indicating that the balanced bilinguals process both languages similarly. Authors have also reported that the N400 was broadly distributed in L1 and for L2, N400 was observed at centro-posterior and anterior sites. The study also concluded that low proficient bilinguals have reduced N400 effect indicating that the ERPs can be a valid tool to measure proficiency level in L2. Braunstein et al, (2012) have reported activation of right hemisphere in processing of semantic violations in bilinguals and the latencies were longer with reduced amplitudes for low proficient bilinguals.

### *4.5.1. Electrode-wise analysis of P600 effect in group II in Kannada and English.*

The ERP responses of all 34 electrodes were analyzed and the mean values of responses in the duration of 500-700ms were measured by using independent component analysis of Matlab software for measuring P600 effect in group II. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of 34 electrodes for syntactically correct and syntactically incorrect sentences in Kannada for group II. Table 63 and 64 represent the mean, median and standard deviations and /Z/ values of P600 component for group II for syntactically correct sentences and syntactically incorrect sentences in Kannada and English respectively.

Table 63.

*Mean, Median and SD values of amplitude of P600 components for group II for syntactically correct and syntactically incorrect sentences in Kannada.*

| **Electro de** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Media n** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| O2 | -.605 | -.642 | .655 | -.464 | -.294 | .650 | -.933 |
| O1 | -.84 | -.68 | .804 | -.50 | -.616 | .501 | -1.456 |
| Oz | -.950 | -.73 | .778 | -.68 | -.61 | .525 | -1.120 |
| Pz | -.007 | -.012 | .832 | .50 | .51 | .711 | -1.829 |
| P4 | -.223 | -.212 | .73 | .22 | .01 | .674 | -1.344 |
| P6 | -.315 | -.350 | .671 | .008 | -.102 | .676 | -1.157 |
| P5 | -.665 | -.559 | .727 | -.187 | -.268 | .708 | -1.680 |
| P3 | -.520 | -.415 | .703 | .15 | .011 | .80 | -1.904 |
| Cz | .208 | .157 | .841 | .395 | .451 | .668 | -1.045 |
| C3 | -.350 | -.371 | .685 | .538 | .478 | .852 | -2.72** |
| C5 | -.385 | -.190 | 1.03 | .39 | .33 | .728 | -2.203* |
| C4 | .195 | .16 | .622 | .361 | .268 | .563 | -.971 |
| C6 | .266 | .412 | 1.14 | .748 | .678 | .795 | -1.755 |
| T7 | .004 | .60 | 1.2 | .371 | .458 | .560 | -.597 |
| T8 | .502 | .442 | .594 | .18 | .150 | .41 | -2.427* |
| Fz | -.077 | -.113 | .81 | .18 | .450 | 1.37 | -.933 |
| F3 | -.20 | -.095 | .939 | .049 | -.062 | 1.11 | -.523 |
| F7 | -.27 | .694 | 1.595 | .125 | .120 | .576 | -.672 |
| F4 | .292 | .183 | .45 | .061 | .21 | 1.01 | -.970 |
| F8 | .526 | .755 | 1.11 | .17 | .123 | .972 | -2.016* |
| FT8 | .26 | .269 | .593 | -.077 | .023 | .488 | -2.053* |
| FT7 | -.192 | .626 | 1.51 | .404 | .315 | .830 | -.560 |
| FP1 | -.177 | -.205 | .920 | -.406 | -.592 | 1.51 | -.597 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| FP2 | .057 | -.186 | .729 | .279 | .497 | 1.03 | -.747 |
| FC3 | -.20 | -.118 | .763 | .37 | .165 | 1.04 | -1.344 |
| FC4 | .31 | .32 | .45 | .041 | .084 | .741 | -1.419 |
| FCz | .213 | .115 | .65 | .103 | .147 | 1.17 | -.224 |
| CP5 | -.478 | -.526 | .801 | .118 | -.003 | .64 | -2.128* |
| TP7 | -.382 | .077 | 1.19 | .220 | .097 | .552 | -1.60 |
| TP8 | .28 | .188 | .340 | -.078 | -.020 | .375 | -2.98** |
| CPz | -.050 | -.19 | .88 | .41 | .37 | .76 | -1.829 |
| CP4 | .135 | .028 | .741 | .496 | .52 | .581 | -1.531 |
| CP6 | .174 | -.018 | .77 | .201 | .165 | .479 | -.037 |
| CP3 | -.377 | -.22 | .739 | .285 | .09 | .799 | -1.979* |

Note: *: $p<0.05$; **: $p<0.01$.

In L1, P600 component (positive shift in amplitudes) for syntactically incorrect sentences was observed at O2, O1, Oz, Pz, P4, P6, P5, P3, Cz, C3, C5, C4, C6, Fz, F4, FP2, FC3, FCz, CP5, TP7, CPz, CP4, CP6, and CP3 indicating that the distribution of P600 is broadly distributed over scalp and mainly observed at centro-parietal (CP), parietal (P), and central (C) areas. However, significant differences between syntactically correct and syntactically incorrect sentences were observed at the left central (C3 & C5) and right frontal (F8) and fronto-temporal (FT8), and left centro-parietal (CP5) regions in L1.

Table 64.

*Mean, Median and SD values of amplitude of P600 components for group II for syntactically correct and syntactically incorrect sentences in English.*

| Electrode | Amplitudes for Semantically correct sentences | | | Amplitudes for Semantically incorrect sentences | | | /Z/ |
|---|---|---|---|---|---|---|---|
| | Mean (in µv) | Median | SD (in µv) | Mean (in µv) | Median | SD (in µv) | |
| O2 | -.242 | -.012 | .552 | -.145 | -.071 | .348 | -.224 |
| O1 | -.296 | -.212 | .802 | -.434 | -.333 | .735 | -.935 |
| Oz | -.252 | -.025 | .66 | -.378 | -.340 | .366 | -1.195 |
| Pz | .309 | .369 | .84 | .302 | .234 | 1.06 | -.037 |
| P4 | .05 | .23 | .63 | .122 | .031 | .606 | -.187 |
| P6 | -.040 | .037 | .617 | .04 | -.03 | .41 | -.485 |
| P5 | -.362 | -.139 | .909 | -.144 | -.22 | .621 | -1.381 |
| P3 | .009 | -.062 | .82 | -.077 | -.127 | .622 | -.190 |
| Cz | .121 | .019 | 1.01 | -.123 | -.065 | 1.18 | -.597 |
| C3 | .057 | -.002 | .844 | .060 | .031 | .871 | -.149 |
| C5 | -.050 | -.121 | .869 | .138 | .116 | .727 | -1.120 |
| C4 | .098 | .009 | .75 | .19 | .15 | .89 | -.411 |
| C6 | -.076 | -.013 | .735 | .44 | .33 | .72 | -.597 |
| T7 | -.244 | -.168 | .745 | -.003 | .038 | .60 | -1.045 |
| T8 | .009 | .032 | .639 | .480 | .430 | .467 | -2.203* |
| Fz | -.348 | -.415 | .928 | -.658 | -.30 | .979 | -.635 |
| F3 | -.422 | -.515 | .965 | -.711 | -.47 | .805 | -.784 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| F7 | -.313 | -.513 | .834 | -.488 | -.490 | .633 | -.261 |
| F4 | -.202 | -.266 | .955 | -.535 | -.289 | .958 | -.935 |
| F8 | -.087 | -.011 | 1.00 | -.074 | -.018 | .623 | -.224 |
| FT8 | -.0002 | .13 | .722 | .213 | .15 | .51 | -1.605 |
| FT7 | -.243 | -.235 | .83 | -.133 | .008 | .625 | -.971 |
| FP1 | -.526 | -.528 | 1.209 | -.69 | -.868 | 1.09 | -.373 |
| FP2 | -.350 | -.268 | .853 | -.61 | -.832 | .898 | -1.045 |
| FC3 | -.149 | -.337 | .965 | -.268 | -.24 | .903 | -.336 |
| FC4 | -.093 | -.203 | .824 | -.070 | -.118 | .941 | -.224 |
| FCz | .035 | -.208 | .99 | -.449 | -.463 | 1.22 | -1.381 |
| CP5 | -.263 | -.232 | .805 | .093 | .079 | .516 | -1.605 |
| TP7 | -.384 | -.171 | .843 | .103 | .03 | .499 | -2.053* |
| TP8 | .091 | .002 | .52 | .14 | .08 | .395 | -.336 |
| CPz | .118 | .07 | 1.0 | .15 | .07 | 1.20 | -.149 |
| CP4 | .150 | .117 | .747 | .23 | .12 | .85 | -.373 |
| CP6 | .055 | .172 | .528 | .21 | .21 | .53 | -.709 |
| CP3 | -.067 | -.073 | .86 | .047 | .003 | .747 | -.448 |

Note: *: $p<0.05$; **: $p<0.01$.

In L2, P600 component for syntactically incorrect sentences was observed at C3, C5, C4, C6, T7, T8, F3, FT7, CP5, TP7, TP8, CP6, and CP3. However, significant differences between amplitudes of syntactically correct and syntactically incorrect sentences were observed at only right temporal (T8) and left temporo-parietal (TP7) regions. These results indicate that the similar areas are activated during processing of syntactic information in L1 and L2 in bilinguals, although minor differences were observed in processing. Figure 12 and 13 represent the grand average waveforms of P600 components of group II in Kannada and English respectively.

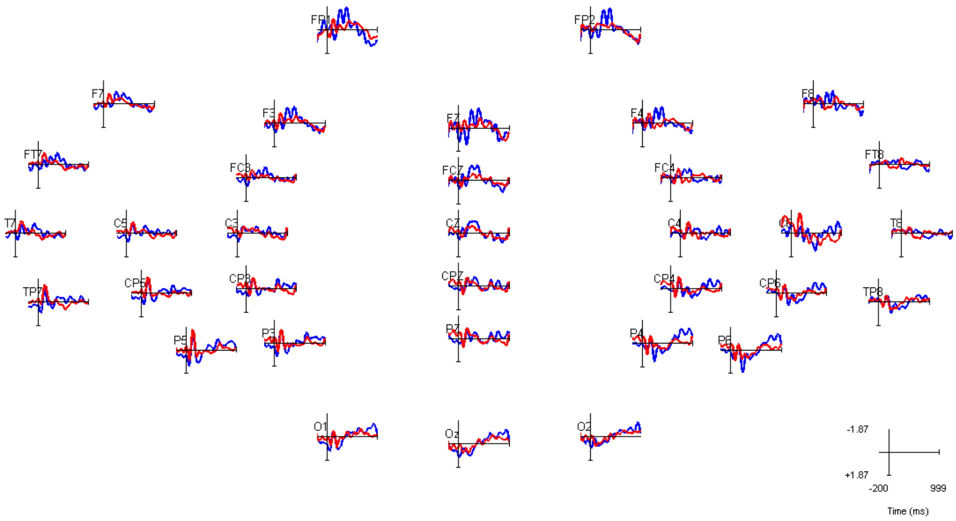


*Figure 12*. Grand average waveforms of 34 electrodes of Group II for syntactically correct and syntactically incorrect sentences in Kannada.

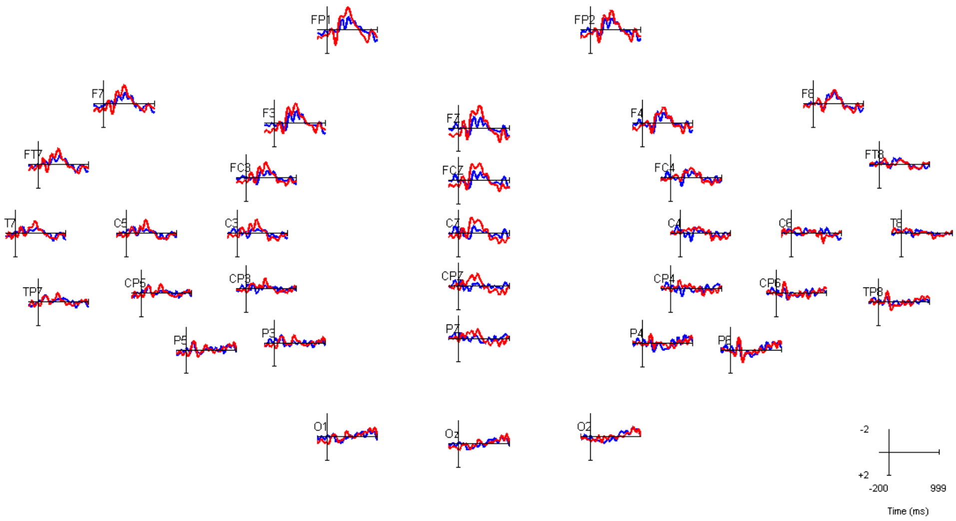


*Figure 13*. Grand average waveforms of 34 electrodes of Group II for syntactically correct and syntactically incorrect sentences in English.

*4.5.1.1. Between electrode comparison for 34 electrodes for Group II of syntactically correct and syntactically incorrect sentences in Kannada.*

Friedman test was conducted to evaluate the differences in amplitudes of 34 electrodes for syntactically correct sentences in Kannada and results revealed significant difference between the electrodes for group II ($\chi^2$ (33) = 161.86, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group II for each type of sentence. Results of pair-wise comparisons between electrodes for group II for syntactically correct sentences in Kannada are given in Table 65.

Table 65.

*Post-hoc results of pair-wise comparisons of 34 electrodes for syntactically correct sentences in Kannada for group II.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | - | - | - | - | - | - | - | - | - | - | + | - | - | + | - | - | - | + | + | + | - | - | + | - | + | + | - | - | + | - | - | + | - |
| O1 | | | - | + | + | - | - | + | + | + | - | + | + | - | + | + | - | - | + | + | + | - | - | + | + | + | + | - | - | + | + | + | + | + |
| Oz | | | | + | - | - | - | + | + | + | - | + | + | - | + | + | + | - | + | + | + | - | - | + | + | + | + | - | - | + | + | + | + | + |
| Pz | | | | | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P4 | | | | | | - | - | - | - | - | - | + | - | - | + | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | + | + | - |
| P6 | | | | | | | - | - | + | + | - | - | + | - | + | - | - | - | + | - | - | - | - | - | - | + | + | - | - | + | - | + | + | - |
| P5 | | | | | | | | - | - | - | - | + | - | - | + | - | - | - | + | + | + | - | - | + | - | + | + | - | + | - | + | - | - | - |
| P3 | | | | | | | | | - | - | - | + | - | - | + | - | - | - | + | - | - | - | - | + | - | + | + | - | - | + | - | - | - | - |
| Cz | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - |
| C3 | | | | | | | | | | | - | - | - | - | + | - | - | - | + | - | - | - | - | - | - | + | + | - | - | + | - | - | - | - |
| C5 | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C4 | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + |
| C6 | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T7 | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | + | - | - | + |
| Fz | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F3 | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

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| F4 | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | + | - | - | + | - | - | - | - | - | + |
| F8 | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - |
| FP2 | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - |
| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | | - | + | - | - | - | - | - | + |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | + |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | + | - | - | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | + |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: p<0.001; -: p>0.001.

Friedman test results revealed significant difference between the electrodes for Group II for syntactically incorrect sentences ($\chi^2$ (33) = 114.71, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group II for syntactically incorrect sentences. Results of pair-wise comparisons between electrodes for group II for syntactically incorrect sentences in Kannada are given in Table 66.

Table 66.

*Post-hoc results of pair-wise comparisons of 34 electrodes for syntactically incorrect sentences in Kannada for group II.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | - | - | + | + | - | - | - | + | + | - | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | + | + | + | - |
| O1 | | | - | + | + | + | - | - | + | + | + | + | + | + | + | - | - | + | - | - | - | + | - | - | + | - | - | + | + | - | + | + | + | + |
| Oz | | | | + | + | + | + | + | + | + | + | + | + | + | + | - | - | + | - | - | - | + | - | + | + | - | - | + | + | + | + | + | + | + |
| Pz | | | | | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P4 | | | | | | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P6 | | | | | | | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P5 | | | | | | | | + | - | + | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | + | + | + | + |
| P3 | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cz | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C3 | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - |
| C5 | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C4 | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - |
| C6 | | | | | | | | | | | | | | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | + | - | - | - | - |
| T7 | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Fz | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F3 | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F4 | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F8 | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | + | - | - |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | + | - | - | - | - | - | - | - | - | - |
| FP | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - |

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| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | + | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | + | - | - |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | + | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: p<0.001; -: p>0.001.

*4.5.1.2. Between electrode comparison for 34 electrodes for Group II of syntactically correct and syntactically incorrect sentences in English.*

Friedman test was conducted to evaluate the differences in amplitudes of 34 electrodes for syntactically correct sentences in English and results revealed significant difference between the electrodes for group II ($\chi^2$ (33) = 86.519, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group II for each type of sentence. Results of pair-wise comparisons between electrodes for group II for syntactically correct sentences in English are given in Table 67.

Table 67.

*Pair-wise comparisons of 34 electrodes for syntactically correct sentences in English for group II.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| O1 | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oz | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Pz | | | | | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - |
| P4 | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P6 | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P5 | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P3 | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cz | | | | | | | | | | - | - | - | - | - | - | - | + | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - |
| C3 | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C5 | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C4 | | | | | | | | | | | | | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C6 | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T7 | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Fz | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - |
| F3 | | | | | | | | | | | | | | | | | | - | - | - | - | - | | - | - | - | + | - | - | - | - | + | - | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F4 | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| F8 | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - |
| FP | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - |

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| 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: p<0.001; -: p>0.001.

Friedman test results revealed significant difference between the electrodes for Group II for syntactically incorrect sentences in English ($\chi^2$ (33) = 151.814, $p$ < .01). Post hoc tests were done using Wilcoxon test to get pair-wise comparisons between electrodes in group II for syntactically incorrect sentences. Results of pair-wise comparisons between electrodes for group II for syntactically incorrect sentences in English are given in Table 68.

Table 68.

*Pair-wise comparisons of 34 electrodes for syntactically incorrect sentences in English for group II.*

| | O2 | O1 | Oz | Pz | P4 | P6 | P5 | P3 | Cz | C3 | C5 | C4 | C6 | T7 | T8 | Fz | F3 | F7 | F4 | F8 | FT8 | FT7 | FP1 | FP2 | FC3 | FC4 | FCz | CP5 | TP7 | TP8 | CPz | CP4 | CP6 | CP3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| O2 | | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| O1 | | | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oz | | | | - | - | + | - | - | - | - | - | - | + | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | + | + | - | - | - | - |
| Pz | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - |
| P4 | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P6 | | | | | | | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P5 | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| P3 | | | | | | | | | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Cz | | | | | | | | | | - | - | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - |
| C3 | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C5 | | | | | | | | | | | | - | - | - | - | + | + | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - |
| C4 | | | | | | | | | | | | | - | - | - | + | + | - | + | - | - | - | - | - | + | + | + | - | - | - | - | - | - | - |
| C6 | | | | | | | | | | | | | | - | - | + | + | + | + | - | - | - | + | + | + | + | + | - | - | - | - | - | - | - |
| T7 | | | | | | | | | | | | | | | - | + | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| T8 | | | | | | | | | | | | | | | | + | + | + | + | - | - | - | + | + | + | - | + | - | - | + | - | - | - | - |
| Fz | | | | | | | | | | | | | | | | | - | - | - | - | + | + | - | - | - | - | - | + | + | + | - | + | + | - |
| F3 | | | | | | | | | | | | | | | | | | - | - | + | + | + | - | - | + | + | - | + | + | + | - | + | + | - |
| F7 | | | | | | | | | | | | | | | | | | | - | - | + | + | - | - | - | - | - | - | + | - | - | - | - | - |
| F4 | | | | | | | | | | | | | | | | | | | | + | + | - | - | - | - | + | - | - | - | - | - | - | - | - |
| F8 | | | | | | | | | | | | | | | | | | | | | - | - | - | + | - | - | - | - | - | - | - | - | - | - |
| FT8 | | | | | | | | | | | | | | | | | | | | | | - | - | + | - | - | - | - | - | - | - | - | - | - |
| FT7 | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - | - |
| FP1 | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - | - |
| FP | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - | - |

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| 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| FC3 | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - | - | - |
| FC4 | | | | | | | | | | | | | | | | | | | | | | | | | | + | - | - | - | + | + | - | - |
| FCz | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - | - |
| CP5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - | - |
| TP7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - | - |
| TP8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - | - |
| CPz | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - | - |
| CP4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - | - |
| CP6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | - |
| CP3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: +: p<0.001; -: p>0.001.

*4.3.1.3. Comparison of amplitudes between Kannada and English for syntactically correct and syntactically incorrect sentences of Group II.*

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of 34 electrodes between Kannada and English for syntactically correct and syntactically incorrect sentences of Group II. /Z/ values group II for syntactically correct sentences and syntactically incorrect sentences are given in Table 69.

Table 69.

*Significant differences between Kannada and English for syntactically correct and syntactically incorrect sentences in group II.*

| | Correct sentences | /Z/ | Syntactically incorrect sentences | /Z/ |
|---|---|---|---|---|
| O2 | Kan Vs Eng | -1.493 | Kan Vs Eng | -1.531 |
| O1 | Kan Vs Eng | -2.053* | Kan Vs Eng | -.597 |
| Oz | Kan Vs Eng | -2.539* | Kan Vs Eng | -1.979* |
| Pz | Kan Vs Eng | -1.643 | Kan Vs Eng | -.560 |
| P4 | Kan Vs Eng | -1.120 | Kan Vs Eng | -.485 |

| | | | | |
|---|---|---|---|---|
| P6 | Kan Vs Eng | -1.269 | Kan Vs Eng | -.075 |
| P5 | Kan Vs Eng | -1.717 | Kan Vs Eng | -.411 |
| P3 | Kan Vs Eng | -2.352* | Kan Vs Eng | -.933 |
| Cz | Kan Vs Eng | -.261 | Kan Vs Eng | -1.979* |
| C3 | Kan Vs Eng | -1.643 | Kan Vs Eng | -1.680 |
| C5 | Kan Vs Eng | -.896 | Kan Vs Eng | -1.008 |
| C4 | Kan Vs Eng | -.299 | Kan Vs Eng | -.672 |
| C6 | Kan Vs Eng | -1.493 | Kan Vs Eng | -.896 |
| T7 | Kan Vs Eng | -.859 | Kan Vs Eng | -1.941 |
| T8 | Kan Vs Eng | -2.912** | Kan Vs Eng | -1.829 |
| Fz | Kan Vs Eng | -1.419 | Kan Vs Eng | -1.867 |
| F3 | Kan Vs Eng | -.784 | Kan Vs Eng | -2.240* |
| F7 | Kan Vs Eng | -.149 | Kan Vs Eng | -2.576* |
| F4 | Kan Vs Eng | -2.539* | Kan Vs Eng | -2.128* |
| F8 | Kan Vs Eng | -2.24* | Kan Vs Eng | -1.008 |
| FT8 | Kan Vs Eng | -1.680 | Kan Vs Eng | -1.829 |
| FT7 | Kan Vs Eng | -.187 | Kan Vs Eng | -2.053* |
| FP1 | Kan Vs Eng | -1.083 | Kan Vs Eng | -.784 |
| FP2 | Kan Vs Eng | -1.643 | Kan Vs Eng | -2.539* |
| FC3 | Kan Vs Eng | -.037 | Kan Vs Eng | -2.091* |
| FC4 | Kan Vs Eng | -2.277* | Kan Vs Eng | -.485 |
| FCz | Kan Vs Eng | -1.195 | Kan Vs Eng | -1.904 |
| CP5 | Kan Vs Eng | -1.307 | Kan Vs Eng | -.075 |
| TP7 | Kan Vs Eng | -.112 | Kan Vs Eng | -.709 |
| TP8 | Kan Vs Eng | -1.12 | Kan Vs Eng | -1.493 |
| CPz | Kan Vs Eng | -.896 | Kan Vs Eng | -.672 |
| CP4 | Kan Vs Eng | -.112 | Kan Vs Eng | -1.008 |
| CP6 | Kan Vs Eng | -.784 | Kan Vs Eng | -.187 |
| CP3 | Kan Vs Eng | -1.50 | Kan Vs Eng | -.820 |

Note: **: $p<0.01$; *: $p<0.05$.

#### *4.5.2. Scalp region-wise analysis of P600 effect in group II in Kannada and English.*

The ERP responses of all eight scalp regions were analyzed and the mean values of responses in the duration of 500-700ms were measured by using independent component analysis of Matlab software for measuring P600 effect in group II. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of eight scalp regions for syntactically correct and syntactically incorrect sentences in Kannada and English for group II. Table 70 and 71 represent the mean, median and standard deviations and /Z/ values of P600 component for group II for correct sentences and syntactically incorrect sentences in Kannada and English respectively.

Table 70.

*Mean, Median and SD values of amplitude of P600 components of eight scalp regions for group II for syntactically correct and syntactically incorrect sentences in Kannada.*

| **Hemispheric region** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| Left anterior | -.200 | .202 | 1.093 | .070 | -.052 | 1.003 | -.261 |
| Right anterior | .291 | .392 | .483 | .096 | .169 | .782 | -1.493 |
| Left central | .045 | .139 | .588 | .083 | .135 | .814 | -.149 |
| Right central | .168 | .075 | .444 | .090 | .283 | .775 | -.373 |
| Left centro-parietal | .106 | .093 | .499 | .086 | .243 | .789 | -.037 |
| Right centro-parietal | .137 | .075 | .466 | .088 | .288 | .781 | -.336 |
| Left posterior | .122 | .072 | .481 | .087 | .270 | .785 | -.224 |
| Right posterior | .129 | .064 | .473 | .088 | .283 | .783 | -.261 |

Note: *: p<0.05; **: p<0.01.

In L1, higher positive activation levels (P600) for syntactically incorrect sentences were observed for bilateral centro-parietal (CP) and posterior (P) regions, and right central scalp region.

Table 71.

*Mean, Median and SD values of amplitude of P600 components of eight scalp regions for group II for syntactically correct and syntactically incorrect sentences in English.*

| Hemispheric region | Amplitudes for Semantically correct sentences | | | Amplitudes for Semantically incorrect sentences | | | /Z/ |
|---|---|---|---|---|---|---|---|
| | Mean (in µv) | Media n | SD (in µv) | Mean (in µv) | Median | SD (in µv) | |
| Left anterior | -.401 | -.392 | .841 | -.479 | -.397 | .685 | -.037 |
| Right anterior | -.104 | -.164 | .699 | -.216 | -.067 | .677 | -.075 |
| Left central | -.288 | -.308 | .740 | -.348 | -.208 | .645 | -.176 |
| Right central | -.132 | -.197 | .755 | -.282 | -.084 | .652 | -.261 |
| Left centro-parietal | -.210 | -.265 | .633 | -.315 | -.132 | .646 | -.149 |
| Right centro-parietal | -.211 | -.243 | .656 | -.298 | -.095 | .649 | -.037 |
| Left posterior | -.178 | -.254 | .606 | -.307 | -.114 | .647 | -.373 |
| Right posterior | -.185 | -.248 | .664 | -.303 | -.104 | .648 | -.187 |

Note: *: p<0.05; **: p<0.01.

In L2, higher positive activation levels (P600 component) for syntactically incorrect sentences were observed across bilateral central, centro-parietal, posterior and right anterior regions. However, these differences were not statistically significant as revealed by Wilcoxon signed ranks test in both L1 and L2.

*4.3.2.1. Comparison of eight scalp regions for Group II of syntactically correct and syntactically incorrect sentences in Kannada.*

Friedman test was conducted to investigate the scalp region activation differences in amplitudes of eight regions for correct sentences in Kannada and results revealed no significant difference between the regions for syntactically correct sentences ($\chi^2$ (7) = 0.00, $p$ > .05) and also for syntactically incorrect sentences ($\chi^2$ (7) = 1.40, $p$ > .05) for group II.

*4.3.2.2. Between scalp region comparison for eight regions for Group II of syntactically correct and syntactically incorrect sentences in English.*

Friedman test was conducted to investigate the scalp region activation differences in amplitudes of eight regions for correct sentences in Kannada and results revealed no significant difference between the regions for syntactically correct sentences ($\chi^2$ (7) = 7.967, $p > .05$) and also for syntactically incorrect sentences ($\chi^2$ (7) = 2.24, $p > .05$) for group II.

*4.2.2.3. Comparison of amplitudes between Kannada and English for syntactically correct and syntactically incorrect sentences of Group II across eight scalp regions.*

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of eight scalp regions between Kannada and English for syntactically correct and syntactically incorrect sentences for group II. /Z/ values group II are given in Table 72 for syntactically correct and syntactically incorrect sentences.

Table 72.

*Significant differences between Kannada and English for* syntactically *correct and* syntactically *incorrect sentences in group II.*

| **Scalp region** | **Correct sentences** | **/Z/** | **Semantically incorrect sentences** | **/Z/** |
|---|---|---|---|---|
| Left anterior | Kan Vs Eng | -.448 | Kan Vs Eng | -2.016* |
| Right anterior | Kan Vs Eng | -2.539* | Kan Vs Eng | -1.643 |
| Left central | Kan Vs Eng | -1.605 | Kan Vs Eng | -1.941 |
| Right central | Kan Vs Eng | -2.165* | Kan Vs Eng | -1.645 |
| Left centro-parietal | Kan Vs Eng | -1.867 | Kan Vs Eng | -1.941 |
| Right centro-parietal | Kan Vs Eng | -2.053* | Kan Vs Eng | -1.867 |
| Left posterior | Kan Vs Eng | -1.886 | Kan Vs Eng | -1.679 |
| Right posterior | Kan Vs Eng | -1.904 | Kan Vs Eng | -1.867 |

Note: *: p<0.05; **: p<0.01.

Comparison between activation levels in L1 and L2 for each type of sentence across eight scalp regions revealed significant differences between two languages at right anterior, right central and right centro-parietal regions for correct sentences. For syntactically incorrect sentences, significant differences were observed only at left anterior region.

### *4.5.3. Hemispheric activation analysis of P600 effect in group II in Kannada and English.*

The ERP responses of all three hemispheric regions were analyzed and the mean values of responses in the duration of 500-700ms were measured by using independent component analysis of Matlab software for measuring P600 effect in group II. Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of three hemispheric regions for syntactically correct and syntactically incorrect sentences in Kannada and English for group II. Table 73 and 74 represent the mean, median and standard deviations and /Z/ values of P600 component for group II for syntactically correct sentences and syntactically incorrect sentences in Kannada and English respectively.

Table 73.

*Mean, Median and SD values of amplitude of P600 components of three hemispheric regions for group II for* syntactically *correct and* syntactically *incorrect sentences in Kannada.*

| **Hemispheric region** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| Right hemisphere | .134 | .476 | .129 | .216 | .389 | .182 | -.485 |
| Central region | -.111 | .639 | .-237 | .187 | .71 | .202 | -1.157 |
| Left hemisphere | -.340 | .820 | -.081 | .124 | .620 | .056 | -1.381 |

Note: *: p<0.05; **: p<0.01.

Results of hemispheric activation analysis in L1 revealed greater positive activation seen for syntactically incorrect sentences than syntactically correct sentences in left and central regions.

Table 74.

*Mean, Median and SD values of amplitude of P600 components of three hemispheric regions for group II for syntactically correct and syntactically incorrect sentences in English.*

| **Hemispheric region** | **Amplitudes for Semantically correct sentences** | | | **Amplitudes for Semantically incorrect sentences** | | | **/Z/** |
|---|---|---|---|---|---|---|---|
| | **Mean (in µv)** | **Median** | **SD (in µv)** | **Mean (in µv)** | **Median** | **SD (in µv)** | |
| Right hemisphere | -.037 | .581 | -.051 | .047 | .483 | .068 | -.672 |
| Central region | -.019 | .732 | -.044 | -.117 | .729 | -.218 | -.187 |
| Left hemisphere | -.236 | .779 | -.237 | -.186 | .494 | .031 | -.188 |

Note: *: p<0.05; **: p<0.01.

In L2, positive activation for syntactically incorrect sentences (P600 component) is observed in both right and left hemispheres although the difference is not statistically significant.

*4.3.3.1. Comparison of three hemispheric regions of group II for syntactically correct and incorrect sentences in Kannada.*

Friedman test results revealed no significant difference between three hemispheric regions for Group II for syntactically correct sentences ($\chi^2$ (2) =5.20, $p$ > .05) and for syntactically incorrect sentences ($\chi^2$ (2) = 2.10, $p$ > .05) in Kannada.

*4.3.3.2. Comparison of three hemispheric regions of group II for syntactically correct and incorrect sentences in English.*

Friedman test results revealed no significant difference between three hemispheric regions for Group II for syntactically correct sentences ($\chi^2$ (2) = 1.20, $p$ > .05). However, Friedman test results revealed significant differences between three hemispheric regions for syntactically incorrect sentences ($\chi^2$ (2) = 6.30, $p$ < .05) in English. Wilcoxon post-hoc test results are given in Table 75.

Table 75.

*Pair-wise comparisons of three hemispheric regions for syntactically incorrect sentences in English for group II.*

| | Right hemisphere | Central region | Left hemisphere |
|---|---|---|---|
| Right hemisphere | | -1.792 | -2.576* |
| Central region | | | -.448 |
| Left hemisphere | | | |

*: $p<0.05$.

*4.5.3.3. Comparison of amplitudes between Kannada and English for syntactically correct and syntactically incorrect sentences of Group II across three hemispheric regions.*

Pair-wise comparisons were carried out using Wilcoxon signed ranks test to compare the amplitudes of three hemispheric regions between Kannada and English for syntactically correct and syntactically incorrect sentences for group II. /Z/ values group II are given in Table 76 for syntactically correct and syntactically incorrect sentences.

Table 76.

*Significant differences between Kannada and English for* syntactically *correct and* syntactically *incorrect sentences in group II.*

| | **Correct sentences** | **/Z/** | **Syntactically incorrect sentences** | **/Z/** |
|---|---|---|---|---|
| Right hemisphere | Kan Vs Eng | -1.456 | Kan Vs Eng | -1.008 |
| Central hemisphere | Kan Vs Eng | -.709 | Kan Vs Eng | -1.269 |
| Left hemisphere | Kan Vs Eng | -.485 | Kan Vs Eng | -1.792 |

Note. *: $p<0.05$.

Comparison between activation levels in L1 and L2 for each type of sentence across three hemispheric regions revealed no significant difference in three hemispheric regions for both correct and syntactically incorrect sentences.

***General discussion on syntactic processing in typical bilinguals***

The results of the present study revealed that a late positive shift also called as positive syntactic shift or P600 component was present for syntactic violations in both L1 and L2 in bilinguals. P600 component was thought to be elicited by the process of syntactic repair for syntactically violated or phrase violated stimuli. The presence of late positive shift/P600 indicate that the subject is using the syntactic repair process in order to judge the sentence on its grammatical structure which may also involve some amount of semantic information. The results of the present study are supported by few of the earlier studies on syntactic processing in high and low proficient bilinguals. The earliest study on syntactic processing is by Weber-Fox and Neville (1996) who have studied ERPs responses to syntactic violations in Chinese-English bilingual individuals who were exposed to L2 at different age levels on syntactic judgment task. Results revealed that positive syntactic shift at around 500-700ms for phrase structure violations was present in individuals who were exposed to L2 before the age of 10 years which is similar to responses of monolinguals. However, a late positive shift was observed at approximately after 700 ms for phrase structure violations in individuals who were exposed to L2 at the age of 11-13 years. Whereas, for bilinguals who were exposed to L2 after 16 years of age did not elicit P600 component indicating delay in exposure to language may have effect on syntactic processing abilities. These results also indicate that the late bilinguals do not use the syntactic repair process during grammaticality judgment task. The present study results revealed presence of syntactic positive shift at around 500-700 ms in typical bilinguals who were early, high proficient bilinguals. Hahne and Freiderici (2001) have reported that early left anterior negativity (ELAN) which indicates first-pass parsing of syntactic structures was absent in L2 of bilinguals compared to L1 and monolinguals. They have also reported absence of P600 effect for syntactic violations in 20 late Japanese-German bilinguals. This study supports the previous finding by Weber-Fox and Neville (1996). Similar results were also found by Hahne (2001) who reported absence of ELAN in L2 of late Russian-German bilinguals. However, Hahne (2001) found P600 effect in both L1 and L2 of late bilinguals for syntactic violations indicating similar syntactic integration and repair processes in bilinguals.

Study by Proverbio et al (2002) reported that syntactic violations in L1 elicited P600 effect bilaterally and syntactic violations in L2 elicited P600 effect majorly in right hemisphere in early Italian-Slovenian bilinguals. These results indicated differential processing of two languages in early, high proficient bilinguals may be because of differences in neural organization and also minor differences in proficiency levels. Similar type of differential processing is found in the present study. However, the differences in processing of Kannada and English may also be due to the differences in syntactic structures between them along with other factors such as proficiency, age of acquisition, exposure levels and so on.

Weber and Lavric (2008) have reported different results to syntactic violations in German-English bilinguals. The study reported that P600 effect was found for syntactic violations in both L1 and L2 along with N400 effect in L2 for morphosyntactic violations indicating involvement of lexico-semantic system in processing syntactic information in L2. Topographical analysis by Guo et al (2009) has reported that P600 effect to syntactically violated (verb sub-categorization) sentences was distributed broadly in bilinguals. Moreno et al (2010) have studied syntactic processing in monolinguals and bilinguals and reported that P600 effect was present in both monolinguals and bilinguals. Syntactic violations have also resulted in early left anterior negativity (ELAN) indicating use of parsing strategies by both mono and bilinguals. The results were also correlated positively with executive functioning and age of acquisition and proficiency levels. It was also noted that the mean amplitudes of P600 effect were lesser in bilinguals than in monolinguals which was attributed to involvement of control mechanisms in bilinguals during processing of syntactic information. The results of the present study were also supported by a study by Cheng et al (2012) who reported differential processing of various morphosyntactic structures in Chinese-English bilinguals and differences were also found between processing of L1 and L2 which were attributed to late acquisition of L2 in these bilinguals.

***Objective 3: To explore the impact of brain damage on language processing in L1 and L2.***

To explore the impact of brain damage, comparisons were made between group I and group II for three types of sentences and electrophysiological measures at electrode level, scalp region and hemispheric regions.

*4.6.1. Comparison of N400 effect between group I and group II at electrode level*

Mann-Whitney U test was done to compare amplitudes of all 34 electrodes for group I and group II for correct and semantically incorrect sentences in Kannada and English. Results of Mann-Whitney U test for correct and semantically incorrect sentences in Kannada between clinical and typical groups are given in Table 77.

Table 77.

*/Z/ values of Mann-Whitney U test results between group I and group II for correct and semantically incorrect sentences in Kannada.*

| Sl. No | Electrode | /Z/ for correct sentences in Kannada | /Z/ for semantically incorrect sentences in Kannada |
|---|---|---|---|
| 1 | O2 | -1.244 | -.054 |
| 2 | O1 | -1.407 | -2.110* |
| 3 | Oz | -.866 | -.866 |
| 4 | Pz | -.460 | -2.732** |
| 5 | P4 | -2.191* | -3.462** |
| 6 | P6 | -2.462* | -3.787** |
| 7 | P5 | -1.163 | -1.109 |
| 8 | P3 | -.676 | -.406 |
| 9 | Cz | -.108 | -1.569 |
| 10 | C3 | -.812 | -.812 |
| 11 | C5 | -.081 | -1.488 |
| 12 | C4 | -1.407 | -3.003** |
| 13 | C6 | -.568 | -2.218* |
| 14 | T7 | -.352 | -1.163 |
| 15 | T8 | -1.515 | -2.245* |
| 16 | Fz | -1.866 | -2.894* |
| 17 | F3 | -.784 | -3.084** |
| 18 | F7 | -1.136 | -2.597** |
| 19 | F4 | -1.028 | -1.921 |
| 20 | F8 | -.622 | -1.109 |
| 21 | FT8 | -.325 | -1.217 |
| 22 | FT7 | -.216 | -.460 |
| 23 | FP1 | -2.002* | -2.921** |
| 24 | FP2 | -1.271 | -4.193** |
| 25 | FC3 | -.108 | -1.677 |
| 26 | FC4 | -.541 | -.730 |
| 27 | FCz | -1.136 | -.541 |
| 28 | CP5 | -.325 | -.676 |
| 29 | TP7 | -.243 | -.541 |
| 30 | TP8 | -2.435* | -4.355** |
| 31 | CPz | -.162 | -2.894** |
| 32 | CP4 | -2.029* | -3.435** |
| 33 | CP6 | -2.535* | -3.814** |
| 34 | CP3 | -.352 | -2.083* |

Note: *p<0.05; **p<0.01.

In L1, electrode-wise comparison of activation levels between typical and clinical groups revealed significant differences at P4, P6, FP1, TP8, CP4, and CP6 for semantically correct sentences. For semantically incorrect sentences in L1, comparison of activation levels between typical and clinical group revealed significant differences at O1, Pz, P4, P6, C4, C6, T8, Fz, F3, F7, FP1, FP2, TP8, CPz, CP4, CP6, and CP3. Results of Mann-Whitney U test for semantically correct and semantically incorrect sentences in English between group I and II are given in Table 78.

Table 78.

*/Z/ values of Mann-Whitney U test results between group I and group II for semantically correct and semantically incorrect sentences in English.*

| Sl. No | Electrode | /Z/ for correct sentences in English | /Z/ for semantically incorrect sentences in English |
|---|---|---|---|
| 1 | O2 | -2.678** | -2.002* |
| 2 | O1 | -3.706** | -2.786** |
| 3 | Oz | -2.191* | -3.246** |
| 4 | Pz | -2.868** | -.216 |
| 5 | P4 | -2.543* | -.379 |
| 6 | P6 | -2.868** | -.108 |
| 7 | P5 | -2.381* | -2.732** |
| 8 | P3 | -2.651** | -.568 |
| 9 | Cz | -2.570** | -1.217 |
| 10 | C3 | -2.705** | -1.163 |
| 11 | C5 | -2.245* | -.216 |
| 12 | C4 | -2.381* | -1.515 |
| 13 | C6 | -3.409** | -2.327* |
| 14 | T7 | -2.164* | -1.921 |
| 15 | T8 | -2.056* | -.839 |
| 16 | Fz | -1.785 | -3.760** |
| 17 | F3 | -3.436** | -3.165** |
| 18 | F7 | -.866 | -2.705** |
| 19 | F4 | -3.598** | -2.949** |
| 20 | F8 | -3.923** | -3.382** |
| 21 | FT8 | -3.679** | -2.381* |
| 22 | FT7 | -2.002* | -1.082 |
| 23 | FP1 | -2.597** | -1.650 |
| 24 | FP2 | -2.408* | -3.436** |
| 25 | FC3 | -2.732** | -1.515 |
| 26 | FC4 | -3.192** | -1.704 |
| 27 | FCz | -2.435* | -2.191* |
| 28 | CP5 | -2.435* | -1.867 |
| 29 | TP7 | -2.029* | -3.192** |
| 30 | TP8 | -3.652** | -.027 |
| 31 | CPz | -3.760** | -.703 |
| 32 | CP4 | -2.381* | -1.488 |
| 33 | CP6 | -2.949** | -1.677 |
| 34 | CP3 | -2.543* | -.379 |

Note: *p<0.05; **p<0.01.

In L2, comparison between typical and clinical groups revealed significant differences at all 34 electrodes for correct sentences and for semantically incorrect sentences, significant differences were found at O2, O1, Oz, P5, C6, Fz, F3, F7, F4, F8, FT8, FP2, FCz, and TP7 (Table 14). These results indicate that individuals with aphasia process semantically correct sentences in L1 similar to that of typical individuals. While the processing of semantically violated sentences in Kannada and English are affected when compared to typical individuals.

*4.6.2. Comparison of N400 effect between group I and group II at scalp region level.*

Mann-Whitney U test was done to compare amplitudes of eight scalp regions for clinical and typical groups for correct and semantically incorrect sentences in Kannada and English. Results of Mann-Whitney U test for correct and semantically incorrect sentences in Kannada between clinical and typical groups are given in Table 79.

Table 79.

*/Z/ values of Mann-Whitney U test between typical and clinical groups for correct and incorrect sentences in Kannada for each scalp region.*

| **Scalp region** | **Z for correct sentences in Kannada** | **Z for semantically incorrect sentences in Kannada** |
|---|---|---|
| Left anterior | -.568 | -2.705** |
| Right anterior | -1.109 | -1.839 |
| Left central | -.243 | -1.407 |
| Right central | -.812 | -2.272* |
| Left centro-parietal | -.325 | -1.325 |
| Right centro-parietal | -2.326* | -3.733** |
| Left posterior | -.271 | -.379 |
| Right posterior | -2.083* | -3.706** |

Note: *: p<0.05; **: p<0.01.

Differences between typical and clinical groups were found at right centro-parietal and right posterior regions for correct sentences in L1. While for semantically incorrect sentences, significant differences between typical and clinical groups were found at left anterior, right anterior, right centro-parietal and right posterior scalp regions. Results of Mann-Whitney U test for correct and semantically incorrect sentences in English between clinical and typical groups are given in Table 80.

Table 80.

*/Z/ values of Mann-Whitney U test between typical and clinical groups for correct and incorrect sentences in English for each scalp region.*

| **Scalp region** | **Z for correct sentences in English** | **Z for semantically incorrect sentences in English** |
|---|---|---|
| Left anterior | -2.895** | -1.975 |
| Right anterior | -3.733** | -3.11** |
| Left central | -2.381* | -.703 |
| Right central | -3.084** | -2.002 |
| Left centro-parietal | -2.570** | -.676 |
| Right centro-parietal | -2.624** | -1.758 |
| Left posterior | -2.408* | -1.407 |
| Right posterior | -2.732** | -.325 |

Note: *: p<0.05; **: p<0.01.

In L2, significant differences were found between typical and clinical groups for all scalp regions for correct sentences and significant differences were found only for right anterior regions for semantically incorrect sentences.

*4.6.3. Comparison of N400 effect between group I and group II at hemispheric level*

Mann-Whitney U test was done to compare amplitudes of three hemispheric regions for clinical and typical groups for correct and semantically incorrect sentences in Kannada and English. Results of Mann-Whitney U test for correct and semantically incorrect sentences in Kannada between clinical and typical groups are given in Table 81.

Table 81.

*/Z/ values of Mann-Whitney U test between typical and clinical groups for correct and incorrect sentences in Kannada for each hemispheric region.*

| **Hemispheric region** | **Z for correct sentences in Kannada** | **Z for semantically incorrect sentences in Kannada** |
|---|---|---|
| Right | -.271 | -1.650 |
| Central | -.622 | -.730 |
| Left | -.216 | -1.001 |

Results of Mann-Whitney U test for correct and semantically incorrect sentences in English between clinical and typical groups are given in Table 82.

Table 82.

*/Z/ values of Mann-Whitney U test between typical and clinical groups for correct and incorrect sentences in English for each hemispheric region.*

| Hemispheric region | Z for correct sentences in English | Z for semantically incorrect sentences in English |
|---|---|---|
| Right | -3.652** | -1.921 |
| Central | -2.841** | -1.407 |
| Left | -2.895** | -.311 |

Note: *: p<0.05; **: p<0.01.

At hemisphere level, significant differences between typical and clinical groups were not found for semantically correct and semantically incorrect sentences in L1. However, in L2, significant differences were found for semantically correct sentences for all three hemispheric regions but no significant differences were found for semantically incorrect sentences in all three hemispheric regions.

*4.7.1. Comparison of P600 effect between group I and group II at electrode level.*

Mann-Whitney U test was done to compare amplitudes of all 34 electrodes for clinical and typical groups for correct and syntactically incorrect sentences in Kannada and English. Results of Mann-Whitney U test for correct and syntactically incorrect sentences in Kannada between clinical and typical groups are given in Table 83.

Table 83.

*/Z/ values of Mann-Whitney U test comparisons between typical and clinical groups in Kannada for each type of sentence.*

| Sl. No | Electrode | /Z/ for correct sentences in Kannada | /Z/ for syntactically incorrect sentences in Kannada |
|---|---|---|---|
| 1 | O2 | -.784 | -3.219** |
| 2 | O1 | -.812 | -.433 |
| 3 | Oz | -1.677 | -3.327** |
| 4 | Pz | -.298 | -2.84** |
| 5 | P4 | -.379 | -2.11* |

| | | | |
|---|---|---|---|
| 6 | P6 | -1.434 | -.839 |
| 7 | P5 | -.893 | -.162 |
| 8 | P3 | -.784 | -1.866 |
| 9 | Cz | -1.596 | -3.165** |
| 10 | C3 | -.108 | -3.084** |
| 11 | C5 | -1.136 | -2.678** |
| 12 | C4 | -.514 | -2.976** |
| 13 | C6 | -.298 | -4.058** |
| 14 | T7 | -.325 | -2.407** |
| 15 | T8 | -1.461 | -1.407 |
| 16 | Fz | -.649 | -2.218* |
| 17 | F3 | -1.353 | -1.461 |
| 18 | F7 | -.352 | -1.488 |
| 19 | F4 | -.108 | -1.65 |
| 20 | F8 | -.162 | -.433 |
| 21 | FT8 | -.325 | -1.298 |
| 22 | FT7 | -1.001 | -2.299* |
| 23 | FP1 | -3.246** | -.541 |
| 24 | FP2 | -2.597** | -.108 |
| 25 | FC3 | -.379 | -2.435* |
| 26 | FC4 | -.162 | -1.731 |
| 27 | FCz | -1.894 | -2.462* |
| 28 | CP5 | -.703 | -1.488 |
| 29 | TP7 | -1.136 | -3.219** |
| 30 | TP8 | -.974 | -.649 |
| 31 | CPz | -.271 | -2.624** |
| 32 | CP4 | -.433 | -3.11** |
| 33 | CP6 | -.487 | -1.65 |
| 34 | CP3 | -.108 | -2.326* |

Note: *: $p<0.05$; **: $p<0.01$.

In L1, electrode-wise comparison of activation levels between typical and clinical groups revealed significant differences at FP1 and FP2 for syntactically correct sentences.

For semantically incorrect sentences in L1, comparison of activation levels between typical and clinical group revealed significant differences at O2, Oz, Pz, P4, Cz, C3, C5, C4, C6, T7, Fz, FT7, FC3, FCz, TP7, CPz, CP4, and CP3. Results of Mann-Whitney U test for correct and syntactically incorrect sentences in English between clinical and typical groups are given in Table 84.

Table 84.

*/Z/ values of Mann-Whitney U test comparisons between typical and clinical groups in Kannada for each type of sentence.*

| **Sl. No** | **Electrode** | **/Z/ for correct sentences in English** | **/Z/ for syntactically incorrect sentences in English** |
|---|---|---|---|
| 1 | O2 | -.352 | -1.704 |
| 2 | O1 | -1.001 | -.162 |
| 3 | Oz | -.379 | -1.19 |
| 4 | Pz | -2.272* | -.595 |
| 5 | P4 | -1.082 | -.379 |
| 6 | P6 | -1.163 | -.568 |
| 7 | P5 | -.162 | -.189 |
| 8 | P3 | -1.731 | -.081 |
| 9 | Cz | -1.65 | -.703 |
| 10 | C3 | -1.136 | -1.028 |
| 11 | C5 | -.920 | -.784 |
| 12 | C4 | -1.325 | -.406 |
| 13 | C6 | -.487 | -.379 |
| 14 | T7 | -1.380 | -1.055 |
| 15 | T8 | -.054 | -.866 |
| 16 | Fz | -.947 | -2.759** |
| 17 | F3 | -1.731 | -3.625** |
| 18 | F7 | -.784 | -3.03** |
| 19 | F4 | -.216 | -2.29* |
| 20 | F8 | -.595 | -1.894 |
| 21 | FT8 | -.568 | -1.380 |

| | | | |
|---|---|---|---|
| 22 | FT7 | -1.65 | -2.678** |
| 23 | FP1 | -2.137* | -3.246** |
| 24 | FP2 | -1.704 | -3.355** |
| 25 | FC3 | -.487 | -2.002* |
| 26 | FC4 | -.189 | -1.028 |
| 27 | FCz | -.839 | -1.38 |
| 28 | CP5 | -1.488 | 0.00 |
| 29 | TP7 | -1.033 | -1.19 |
| 30 | TP8 | -.460 | -.298 |
| 31 | CPz | -1.623 | -.108 |
| 32 | CP4 | -1.271 | 0.00 |
| 33 | CP6 | -.379 | -.189 |
| 34 | CP3 | -1.109 | -.162 |

Note: *: $p<0.05$; **: $p<0.01$.

In L2, comparison between typical and clinical groups revealed significant differences for syntactically correct sentences at only Pz and for syntactically incorrect sentences, significant differences were found at Fz, F3, F7, F4, FT7, FP1, FP2, and FC3.

*4.7.2. Comparison of P600 effect between group I and group II at scalp region level.*

Mann-Whitney U test was done to compare amplitudes of eight scalp regions for clinical and typical groups for correct and syntactically incorrect sentences in Kannada and English. Results of Mann-Whitney U test for correct and syntactically incorrect sentences in Kannada between clinical and typical groups are given in Table 85.

Table 85.

*/Z/ values of Mann-Whitney U test between typical and clinical groups for correct and syntactically incorrect sentences in Kannada for each scalp region.*

| **Scalp region** | **/Z/ for correct sentences in Kannada** | **/Z/ for semantically incorrect sentences in Kannada** |
|---|---|---|
| Left anterior | 1.407 | -.947 |
| Right anterior | -.839 | -.812 |
| Left central | -1.758 | -1.217 |

| | | |
|---|---|---|
| Right central | -1.515 | -1.109 |
| Left centro-parietal | -1.704 | -1.190 |
| Right centro-parietal | -1.569 | -1.186 |
| Left posterior | -1.704 | -1.163 |
| Right posterior | -1.623 | -1.20 |

Note: *: p<0.05; **: p<0.01.

At scalp region level, no significant differences between typical and clinical groups were found at eight scalp regions for both syntactically correct and syntactically incorrect sentences in L1. Results of Mann-Whitney U test for correct and syntactically incorrect sentences in English between clinical and typical groups are given in Table 86.

Table 86.

*/Z/ values of Mann-Whitney U test between typical and clinical groups for correct and incorrect sentences in English for each scalp region.*

| **Scalp region** | **Z for correct sentences in English** | **Z for semantically incorrect sentences in English** |
|---|---|---|
| Left anterior | -1.785 | -3.517** |
| Right anterior | -.027 | -2.137* |
| Left central | -1.082 | -3.246** |
| Right central | -.568 | -2.678** |
| Left centro-parietal | -1.028 | -2.976** |
| Right centro-parietal | -.784 | -2.813** |
| Left posterior | -.866 | -2.894** |
| Right posterior | -.893 | -2.840** |

Note: *: p<0.05; **: p<0.01.

In L2, significant differences were not found between typical and clinical groups for all scalp regions for syntactically correct sentences. However, significant differences were found for all eight scalp regions for syntactically incorrect sentences.

*4.7.3. Comparison of P600 effect between group I and group II at hemisphere level.*

Mann-Whitney U test was done to compare amplitudes of three hemispheric regions for clinical and typical groups for correct and syntactically incorrect sentences in Kannada and English. Results of Mann-Whitney U test for correct and syntactically incorrect sentences in Kannada between clinical and typical groups are given in Table 87.

Table 87.

*/Z/ values of Mann-Whitney U test between typical and clinical groups for correct and syntactically incorrect sentences in Kannada for each hemispheric region.*

| **Hemispheric region** | **/Z/ for correct sentences in Kannada** | **/Z/ for syntactically incorrect sentences in Kannada** |
|---|---|---|
| Right | -.108 | -2.110* |
| Central | -.216 | -2.570** |
| Left | -.893 | -2.029* |

Note: *: p<0.05; **: p<0.01.

At hemisphere level, significant differences between typical and clinical groups were not found for syntactically correct sentences, however, significant differences were found for syntactically incorrect sentences at all three hemispheric regions in L1. Results of Mann-Whitney U test for correct and syntactically incorrect sentences in English between clinical and typical groups are given in Table 88.

Table 88.

*/Z/ values of Mann-Whitney U test between typical and clinical groups for correct and syntactically incorrect sentences in English for each hemispheric region.*

| **Hemispheric region** | **/Z/ for correct sentences in English** | **/Z/ for syntactically incorrect sentences in English** |
|---|---|---|
| Right | -.325 | -1.028 |
| Central | -1.109 | -.568 |
| Left | -.487 | -1.839 |

Note: *: p<0.05; **: p<0.01.

In L2, significant differences were not found for both syntactically correct and syntactically incorrect sentences for all three hemispheric regions.

The differences between typical individuals and individuals with aphasia were also found in studies by Becker and Reinvang (2007) who reported presence of P300 component with differential activation in processing the auditory information in early and late stages of language processing. These results also provided evidence that individuals with aphasia can perform simple tasks but they have major difficulty in processing complex tasks. These results are also supported by the studies of D'Arcy et al (2003), Swaab et al (1997), Friederici et al (1999), Hagoort et al (1996), ter Keurs et al (1999) and Justus et al (2011) who reported that the brain damage results in slowing of processing abilities in clinical population on complex tasks including that of language and cognition tasks. Study on individuals with primary progressive aphasia (PPA) by Giaquinto and Ranghi (2009) have reported significant delay in peak latency by 300 ms and also reduction in amplitude levels of N400 peak on word recognition skills and other cognitive skills. Repeated assessment of language processing skills using ERPs have concluded that ERPs can be used as a reliable tool for diagnosis and monitoring of cognitive decline and language dysfunction in individuals with neurodegenerative disorders.

Results of the present study indicate that the activation levels at occipital regions varied in bilinguals between Kannada and English in occipital regions indicating differential effect of orthographies on neurophysiological mechanisms. This may be because of the structural differences in orthography and syntactic structures between Kannada and English with Kannada being more transparent in orthography where there is a direct relation between the written unit, akshara and the sound. However, this consistent relation is not seen in alphabetic languages like English or syllabic languages such as Japanese. These results are inconsistent with the previous neuroimaging studies done by Polk, et al, 2002 and also the study done by Proverbio et al, 2002 who reported bilateral response in the N1 during the processing of words in Italian (L1) and Left sided response during processing of L2 (Slovenian). This may be due to the differences in distinct orthographies of Kannada (semi-syllabic & semi-alphabetic orthographies; transparent/surface orthography) and English (alphabetic; deep orthography). Overall, these results indicate that word form system might be able to discriminate between different languages on the basis of orthographical analysis at very early stages of visual processing.

**Verification of hypotheses**

The results of the present study have provided evidence to reject the three null hypotheses and accept the alternate hypotheses.

# Chapter V

## Summary and Conclusions

The present study was undertaken to investigate the cortical representations and neurofunctional mechanisms of semantic and syntactic processing of L1 and L2 in Kannada-English bilinguals with aphasia and typical bilinguals. A total of 40 participants with 20 participants each in clinical and typical groups. All the participants were right handed individuals and native speakers of Kannada and learned English as second language from school education. All the individuals with aphasia were diagnosed using WAB-K (Chengappa & Ravikumar, 2008). International Second Language Proficiency Rating Scale (ISLPR: Wylie & Inghram, 2006) was used to assess proficiency in second language in all participants. Part-C (Kannada-English bilingualism) of Bilingual Aphasia Test-Kannada (Rangamani & Paradis, 1987), reading domain of Western Aphasia Battery-Kannada (Chengappa & Ravikumar, 2008) were used to assess general language and reading abilities in all participants.

A total of 150 sentences in each language (50 correct, 50 semantically incorrect and 50 syntactically incorrect) were developed with MLU of 3-6 words for ERP experiment. All the sentences were loaded and presented through Gentask software of STIM2 hardware of Compumedics Neuroscan Inc. All the participants were instructed to read the sentences and judge whether the sentence is correct or incorrect.

EEG recording was continuously recorded from 34 Ag/AgCl electrodes placed according to 10-20 international system during the semantic and syntactic judgment tasks to monitor the brain activity during semantic and syntactic violations. The EEG waveforms were analyzed with independent component analysis of MATLAB software version 2009b to analyze N400 and P600 components in the time window of 300-500ms and 500-700ms respectively. The responses were also analyzed electrode-wise, hemispheric wise, and scalp region wise for both correct and incorrect sentences in both languages.

Non-parametric tests were used for statistical analysis of the ERP data to investigate the objectives of the study. Results of (Mann-Whitney U test, Friedmann test and Wilcoxon signed rank tests) ERP data of typical individuals revealed presence of N400 effect for semantically incorrect sentences which was broadly distributed in left hemisphere for L1 and distributed in both left and right hemispheres for L2 at electrode level, hemispheric level, and scalp region. N400 was observed majorly at left central and posterior scalp regions for L1. While in L2, N400 component was present at left centro-parietal and right posterior regions. Syntactic violations in both L1 and L2 resulted in P600 component in typical group with greater activation levels in left and central regions in L1 and greater activation levels were seen in both right and left hemispheres indicating role of right hemisphere in processing L2 in typical individuals.

Results of ERP data of clinical group showed presence of N400 component for semantically violated sentences with broad scalp distribution over left and right hemispheres in both L1 and L2. Similarly, syntactic violations in both L1 and L2 resulted in P600 component over both left and right hemispheres with major activation in centro-parietal regions indicating involvement of both left and right hemispheres during processing of semantic and syntactic aspects in both L1 and L2.

Comparisons between typical and clinical groups also revealed significant differences in both L1 and L2 for semantic and syntactic violations at electrode level, hemispheric and scalp region levels. Results revealed that individuals with aphasia processed semantically violated sentences similar to that of typical individuals in L1. However, significant differences were observed between typical and clinical groups for processing syntactically violated sentences with reduced amplitudes and prolonged latencies for individuals with aphasia indicating significant deficits in syntactic processing abilities in clinical group.

Significant differences were found between clinical and typical groups on accuracy and reaction time measurements. Clinical group showed lesser accuracy levels for both semantic and syntactic violations and increased reaction times for both semantically and syntactically judgment tasks.

Thus the present study revealed significant differences for language processing between clinical and typical groups over electrophysiological measurements and also over behavioural measurements. The present study also revealed that electrophysiological measures can be a valid tool in assessing language impairments in clinical population.

**Implications of the Study**

1. This study provided information about the nature of language processing in L1 and L2 in bilinguals with and without aphasia.
2. As the languages (Kannada and English) taken in this study are dissimilar in terms of its structure and other linguistic aspects, this study adds to information on how two distinct languages are represented and processed in typical and clinical groups.
3. The experiments on clinical group will provide greater insights into understanding neurofunctional/ physiological/pathological aspects of aphasic group in detail, thus providing directions for intervention.

**Future directions**

1. Although the present study provided insights into neural mechanisms and neural organization of languages in typical bilinguals and individuals with bilingual aphasia,

the results cannot be generalized to all bilingual population due to small sample size. Hence, future studies are required with larger sample to validate and extend the results of the present study.

2. As the sample size is small, effect of various factors in bilingual language processing such as age of second language acquisition, manner of acquisition, proficiency levels could not be studied. Hence, more number of studies are required to explore the effect of each of the above and other variables on language processing in typical bilinguals and also on clinical population.
3. The present study provides ample support to use electrophysiological measures as a valid tool to assess language processing in bilinguals. However, more number of studies are required to validate ERPs as a valid tool to assess language abilities in individuals with aphasia.
4. The present study was limited to study the processing of semantics and syntax of Kannada and English and results provided evidence for differential processing of L1 and L2 in bilinguals. Further studies are required to study the similarities and dissimilarities in bilingual and multilingual language processing in more language pairs/combinations which may be similar or dissimilar in semantic and syntactic structures (Eg., Kannada-Telugu, Telugu-English, etc.).

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## Appendix-A

**Correct Sentences in English**

1. The mother smiles.
2. The wind blows.
3. The boats sail.
4. Two children run.
5. One girl swings.
6. The kite flies.
7. The teacher reads.
8. The girls cheer.
9. The bus driver waits.
10. The nurse helps.
11. I wonder what he thinks.
12. Trees and flowers grow.
13. The washing machine washes.
14. Child likes to walk.
15. The lion escapes.
16. The girl laughed.
17. The train moved.
18. My friend smiled.
19. The doorbell rang.
20. The guests left.
21. The librarian whispered.
22. The little boy fell.
23. The tiger slept.
24. The star twinkled.
25. The ball bounced.
26. The student learned.
27. The car turned.
28. The water boiled.
29. The woman sang.
30. The ship sunk.
31. The sleeves covered both hands.
32. The coat had two big pockets.
33. A cat chased three mice.
34. A baby was playing with a toy mouse.
35. He fell and hit his two front teeth.
36. He works at a school.
37. My sister is having a party.
38. Two boys are swimming in the water.
39. The children played in a park.
40. The tree had many branches.

41. Farmers grow fruit and vegetables.
42. Drivers take packages to cities.
43. The grass is green.
44. The snow is white.
45. The fire is hot.
46. This rock is hard
47. Apples are healthy
48. Games are fun.
49. Bananas are yellow.
50. Needles are sharp.

**Semantically Incorrect Sentecnes in English**

1. The block smiles.
2. A mountain sees.
3. A bottle laughs.
4. The boats run.
5. The tree digs.
6. The rock swims.
7. The sky swings.
8. The papers run.
9. The door dances.
10. The fish reads.
11. The light waits.
12. My kitchen plays.
13. The shirt writes.
14. I wonder what he walks.
15. Trees and flowers quack.
16. The duck drives.
17. The boat walks.
18. The window escapes.
19. The ear drinks.
20. The train eats.
21. The balloon ate.
22. The pencil kicked.
23. The plane cried.
24. The picture ran.
25. The cup whispered.
26. The clock rested.
27. The little cloud fell.
28. The dog drove.
29. The phone threw.
30. The tiger barked.

31. The star swallowed.
32. The waterfall bounced.
33. The house turned.
34. The water yelled.
35. The dolphin jogged.
36. The ship walked.
37. The sleeves covered both moons.
38. The coat had two big legs.
39. She found a key in one ear.
40. The key will open many hangers.
41. Child wore a striped banana.
42. Baby dogs are called worms
43. The animals like to eat pianos.
44. My father drives a hair.
45. His truck has sixteen fingers.
46. He works at a cloud.
47. Many foods come from stars.
48. A king lived in a huge hotdog.
49. Some people build oranges.
50. Farmers grow fruit and monkeys.

**Syntactically Incorrect Sentences in English**

1. Two children runs.
2. They walks to park.
3. The kite fly.
4. They sings Kannada songs.
5. The teacher readed.
6. The driver wait bus.
7. My sister play.
8. The people leaves.
9. The washing machine wash.
10. The lion escape.
11. The train move.
12. The horse kick.
13. The plane flied.
14. The doorbell ringed.
15. His uncle runned.
16. The baby has comed.
17. The guests leaved.
18. The runner rest for a while.
19. The little boy falled.
20. The tiger sleeped.
21. We watching cricket match.

22. The student learn.
23. The waters boil.
24. The woman singed.
25. The artist drawed.
26. The dolphin swimmed.
27. The ship sinked.
28. The cowboy rided.
29. The team losed.
30. The Indian team winned
31. The family eated rice.
32. The strangers meeted.
33. The puppy growed.
34. The sleeves covered both hand.
35. The coat had two big pocket.
36. I kept an apple in one bags.
37. The key will open many door.
38. Raju wore a striped shirts.
39. Did you see this red shirts?
40. How did he look in those dress?
41. A cat chased three mouses.
42. He fell and hit his two front tooths.
43. My father drives a trucks.
44. His truck has sixteen wheel.
45. Dad drives the truck to a factories.
46. His uncle is a cooks.
47. My cousins own a huge houses.
48. A king lived in a huge castles.
49. The tree has many branch.
50. He showed each rooms.

# Appendix-B

## Correct Sentences in Kannada

1. ಬಸ್ಸು ರೋಡಿನ ಮೇಲೆ ಹೋಗುತ್ತಿದೆ.
2. ನಾನು ಊರಿಗೆ ಹೋಗಿದ್ದೆ.
3. ನಾನು ತರಗತಿಯಲ್ಲಿ ಕುಳಿತಿದ್ದೇನೆ.
4. ಜನರು ಕೆಲಸಮಾಡುತ್ತಿದ್ದಾರೆ.
5. ನನಗೆ ಬಾಯಾರಿಕೆಯಾಗಿದೆ.
6. ಹಸು ಹಾಲು ಕೊಡುತ್ತದೆ.
7. ಹುಡುಗರು ಆಟ ಆಡುತ್ತಿದ್ದಾರೆ.
8. ಬೆಕ್ಕು ಮೂರು ಇಲಿಗಳನ್ನು ಹಿಡಿಯಿತ್ತು.
9. ಅಜ್ಜಿ ಅಡಿಗೆ ಮಾಡುತ್ತಿದ್ದಾರೆ.
10. ಅತಿಥಿಗಳು ಬರುತ್ತಾರೆ.
11. ಚಾಲಕ ಕಾರನ್ನು ಚಲಿಸುತ್ತಿದ್ದಾನೆ.
12. ನಾವು ಚಲನಚಿತ್ರವನ್ನು ನೋಡುತ್ತಿದ್ದೆವು.
13. ಹಸು ಹುಲ್ಲನ್ನು ತಿನ್ನುತ್ತಿದೆ.
14. ಅವರು ಊಟ ಮಾಡುತ್ತಿದ್ದಾರೆ.
15. ನದಿಗಳು ಸಮುದ್ರವನ್ನು ಸೇರುತ್ತವೆ.
16. ನಾನು ಅಂಗಡಿಗೆ ಹೋಗಿದ್ದೆ.
17. ಅವನು ಶಾಲೆಯಲ್ಲಿ ಕೆಲಸಮಾಡುತ್ತಾನೆ.
18. ರಾಜ ಅರಮನೆಯಲ್ಲಿ ವಾಸಮಾಡುತ್ತಾನೆ.
19. ಮಕ್ಕಳು ಮರವನ್ನು ಹತ್ತುತ್ತಿದ್ದರು.
20. ರೈತನು ಬೆಳೆಯನ್ನು ಬೆಳೆಯುತ್ತಾನೆ.
21. ಗಾಳಿಪಟ ಆಕಾಶದಲ್ಲಿ ಹಾರುತ್ತಿದೆ.
22. ರಾಣಿ ಎಲ್ಲರಿಗೂ ಊಟವನ್ನು ಹಾಕಿಸಿದಳು.
23. ಕೆಲಸಗಾರರು ಮನೆಯನ್ನು ಕಟ್ಟುತ್ತಾರೆ.
24. ಹುಡುಗಿಯರು ದೇವಸ್ಥಾನಕ್ಕೆ ಹೋಗುತ್ತಿದ್ದಾರೆ.
25. ಮಕ್ಕಳಿಗೆ ಸಿಹಿತಿನಿಸು ಎಂದರೆ ತುಂಬಾ ಇಷ್ಟ.
26. ವೈದ್ಯರು ಔಷಧಿಯನ್ನು ಕೊಡುತ್ತಾರೆ.
27. ವಿಮಾನ ಆಕಾಶದಲ್ಲಿ ಹಾರುತ್ತದೆ.
28. ಎಲೆಗಳು ಹಸಿರು ಬಣ್ಣದಲ್ಲಿ ಇರುತ್ತವೆ.
29. ಕೆಲಸಗಾರರು ರಜೆ ಹಾಕಿದ್ದಾರೆ.
30. ನಾನು ನಿನ್ನೆ ಊರಿಗೆ ಹೋಗಿದ್ದೆ.
31. ಸೂರ್ಯ ಬೆಳಕನ್ನು ನೀಡುತ್ತಾನೆ.
32. ನಾಯಿಗಿಂತ ಕುದುರೆ ದೊಡ್ಡದು.
33. ಕಾಗೆ ಕಪ್ಪಾಗಿದೆ, ಹಂಸ ಬೆಳ್ಳಗಿದೆ.
34. ನೀರು ಲೋಟದ ಒಳಗೆ ಇದೆ.
35. ಹೆಂಗಸು ಹುಡುಗಿಗೆ ಭತ್ತಿಯನ್ನು ಕೊಟ್ಟಳು.
36. ಸೇಬು ಮೇಜಿನ ಮೇಲೆ ಇದೆ.
37. ಅವರು ಕೈಯಿಂದ ಚಪ್ಪಾಳೆ ತಟ್ಟುತ್ತಾರೆ.
38. ಹೆಂಗಸು ಬಾವಿಯಿಂದ ನೀರನ್ನು ಸೇದುತ್ತಿದ್ದಾಳೆ.
39. ಅವಳು ಬಟ್ಟೆಗಳನ್ನು ಒಗೆಯುತ್ತಿದ್ದಾಳೆ.
40. ಬಾಳೆ ಹಣ್ಣಿಗಿಂತ ಕುಂಬಳಕಾಯಿ ಭಾರವಾಗಿದೆ.
41. ಮಳೆ ಬಂದರೆ ಛತ್ರಿ ಉಪಯೋಗಿಸಬೇಕು.
42. ತಟ್ಟೆಯಲ್ಲಿ ಹಣ್ಣುಗಳಿವೆ.
43. ಕೋಳಿ ಅಕ್ಕಿಯನ್ನು ತಿನ್ನುತ್ತದೆ.

44. ಅವರು ಓದುತ್ತಿಲ್ಲ ಏಕೆಂದರೆ ದೀಪವಿಲ್ಲ.
45. ಕುದಿಯುತ್ತಿರುವ ಹಾಲು ಪಾತ್ರೆಯಿಂದ ಚೆಲ್ಲಿತ್ತು.
46. ಪಕ್ಷಿಗಳು ಗೂಡಿನಲ್ಲಿ ಇವೆ.
47. ಅವರು ಕನ್ನಡ ಚೆನ್ನಾಗಿ ಓದುತ್ತಾರೆ.
48. ನನಗೆ ಕೆಂಪು ಬಣ್ಣದ ಟೋಪಿ ಬೇಕು.
49. ಆ ಮನೆಯ ಮೇಲೆ ದೊಡ್ಡ ಮರ ಬಿದ್ದಿದೆ.
50. ಅವಳ ಚೀಲದಲ್ಲಿ ಪುಸ್ತಕಗಳು ಇವೆ.

**Semantically Incorrect Sentences in Kannada**

1. ಹಾಲಿನ ಬಣ್ಣ ಹಸಿರು.
2. ಆ ಹೆಂಗಸು ಅವಳ ತಂದೆ.
3. ಹಗಲಿನಲ್ಲಿ ಚಂದ್ರನು ಪ್ರಕಾಶಮಾನವಾಗಿ ಇರುತ್ತಾನೆ.
4. ಹಾಗಲಕಾಯಿ ಸಿಹಿಯಾಗಿರುತ್ತದೆ.
5. ನಾವು ಕಿವಿಯಿಂದ ಉಸಿರಾಡುತ್ತೇವೆ.
6. ನಾವು ಕೈಯಿಂದ ನಡೆಯುತ್ತೇವೆ.
7. ಕುದುರೆಯು ಆಕಾಶದಲ್ಲಿ ಹಾರುತ್ತದೆ.
8. ಇಂದಿರ ಒಬ್ಬ ಹುಡುಗ.
9. ಸಿಂಹವು ಸಾಕು ಪ್ರಾಣಿ.
10. ಈ ಹುಡುಗಿ ಆ ಹುಡುಗನ ಅಣ್ಣ.
11. ಇವನ ತಮ್ಮನು ಇವನಿಗಿಂತ ದೊಡ್ಡವನು.
12. ಕಲ್ಲು ಮೃದುವಾಗಿರುತ್ತದೆ.
13. ವಿಮಾನ ಒಂದು ಹೂವು.
14. ಮಾವಿನ ಹಣ್ಣು ಖಾರವಾಗಿರುತ್ತದೆ.
15. ಟೀ ಉಪ್ಪಾಗಿರುತ್ತದೆ.
16. ಬೇವಿನ ಎಲೆ ಸಿಹಿಯಾಗಿರುತ್ತದೆ.
17. ಬೇಸಿಗೆಯಲ್ಲಿ ಮಳೆ ಇರುತ್ತದೆ.
18. ಇರುವೆಗಳು ಸಕ್ಕರೆ ತಿನ್ನುವುದಿಲ್ಲ.
19. ಇದ್ದಿಲು ಬಿಳಿ ಬಣ್ಣದಲ್ಲಿ ಇರುತ್ತದೆ.
20. ಹುಲಿ ಆನೆಗಿಂತ ದೊಡ್ಡದಾಗಿರುತ್ತದೆ.
21. ನಾನು ತಟ್ಟೆಯನ್ನು ಒದುತ್ತೇನೆ.
22. ಈ ಸ್ಥಳ ನಿಜವಾಗಿ ಹಸಿವಾಗಿತ್ತು.
23. ನಾವು ನಿಂಬೆಹಣ್ಣಿನಲ್ಲಿ ಕಾರನ್ನು ಹಾಕುತ್ತೇವೆ.
24. ನನ್ನ ಅಣ್ಣ ನನಗಿಂತ ಚಿಕ್ಕವನು.
25. ರಮೇಶ ನನ್ನ ತಂಗಿ.
26. ಕುರ್ಚಿ ವೇಗವಾಗಿ ಓಡುತ್ತದೆ.
27. ಬೆಂಕಿ ತಣ್ಣಗಿರುತ್ತದೆ.
28. ಸೂರ್ಯ ಬೆಳಗ್ಗೆ ಮುಳುಗುತ್ತಾನೆ.
29. ಬದನೆಕಾಯಿ ಒಂದು ಹಣ್ಣು.
30. ನಾವು ಸಾಕ್ಸ್ ಗಳನ್ನು ಕೈಗೆ ಧರಿಸುತ್ತೇವೆ.
31. ಹೂಗಳು ಪಾತ್ರೆಯಲ್ಲಿ ಬೆಳೆಯುತ್ತವೆ.
32. ಕಾರನ್ನು ಚಲಾಯಿಸಲು ನೀರನ್ನು ಬಳಸುತ್ತೇವೆ.
33. ಅವನು ಬೆಳಗ್ಗೆ ಹಾಡುವನ್ನು ತಿಂದನು.
34. ಅವರು ಮರಳನ್ನು ಬಿಸಿಯಾಗಿರುವಾಗ ಕುಡಿಯಿತ್ತಾನೆ.
35. ಸೇಬು ಒಂದು ಪ್ರಾಣಿ.

36. ನಾವು ರೇಡಿಯೋನಲ್ಲಿ ಚಿತ್ರ ನೋಡುತ್ತೇವೆ.
37. ನಾವು ಕಲ್ಲನ್ನು ತಿನ್ನುತ್ತೇವೆ.
38. ನಾವು ಮಂಚದಮೇಲೆ ನಿಂತುಕೊಳ್ಳುತ್ತೇವೆ.
39. ಆಕಾಶ ಹಸಿರು ಬಣ್ಣದಲ್ಲಿ ಇರುತ್ತದೆ.
40. ಅವಳು ಸಾಬೂನಿಂದ ತಲೆ ಬಾಚಿಕೊಳ್ಳುತ್ತಾಳೆ.
41. ನಾವು ಗೋಡೆಯಲ್ಲಿ ಮುಖವನ್ನು ನೋಡಿಕೊಳ್ಳುತ್ತೇವೆ.
42. ಗಿಣಿ ಕಪ್ಪು ಬಣ್ಣದಲ್ಲಿ ಇರುತ್ತದೆ.
43. ನಮಗೆ ಎಂಟು ಬೆರಳುಗಳು ಇರುತ್ತವೆ.
44. ದೀಪ ಗಾಳಿ ಕೊಡುತ್ತದೆ.
45. ಅವರು ಬಸ್ ನಿಲ್ದಾಣದಲ್ಲಿ ರೈಲನ್ನು ಅತ್ತುತ್ತಾರೆ.
46. ನಾವು ಟೋಪಿಯನ್ನು ಕಾಲಿಗೆ ಹಾಕುತ್ತೇವೆ.
47. ನಾವು ಕಿಟಕಿಯಿಂದ ಮನೆ ಒಳಗೆ ಬರುತ್ತೇವೆ.
48. ನಾಯಿ ಚಂದ್ರನನ್ನು ಕಚ್ಚಿತ್ತು.
49. ಒಂದು ಬೆಟ್ಟ ನೋಡುತ್ತದೆ.
50. ಮೀನುಗಳು ನೀರಿನಲ್ಲಿ ನಡೆಯುತ್ತವೆ.

## Syntactically Incorrect Sentences in Kannada

1. ಮಕ್ಕಳು ರಸ್ತೆಯಲ್ಲಿ ನಿಂತಿದೆ.
2. ಇಲ್ಲಿ ಇರುವ ಚಾಕು ಚೂಪಾಗಿವೆ.
3. ಆ ಮರದ ಎಲೆಗಳು ದೊಡ್ಡದಾಗಿದೆ.
4. ರಾಮನ ಹಲ್ಲು ಬಿಳಿಯಾಗಿವೆ.
5. ಅಲ್ಲಿ ನಿಂತಿರುವರು ದಪ್ಪಾಗಿದ್ದಾನೆ.
6. ನೀರಿನಲ್ಲಿ ಮೀನು ಈಜುತ್ತೇವೆ.
7. ಆ ಮನೆಯಲ್ಲಿ ಬೆಕ್ಕು ಇವೆ.
8. ಶಂಕರನ ತೋಟದಲ್ಲಿ ಮರಗಳು ದೊಡ್ಡದಾಗಿದೆ.
9. ಆ ಹೆಂಗಸರು ಹೆಣೆಯುತ್ತಿದ್ದಾಳೆ.
10. ಶಾಲೆಯಲ್ಲಿ ಹುಡುಗಿಯರು ಚಿತ್ರ ಬರೆಯುತ್ತಿದ್ದಾಳೆ.
11. ಅವನು ಸೈಕಲ್ ಹೊಡೆಯುತ್ತಿದ್ದಾಳೆ.
12. ಅವಳು ನದಿಯಲ್ಲಿ ಈಜುತ್ತಿದ್ದಾನೆ.
13. ರಂಜನಿ ತಂಗಿ ಬರುತ್ತಾನೆ.
14. ಅವು ಅಲ್ಲಿ ಮಲಗಿದ್ದಾರೆ.
15. ನಾನು ಚಿತ್ರ ನೋಡುವಳು.
16. ನೀನು ಅಲ್ಲಿ ಬರುತ್ತಾನೆ.
17. ಅವರು ಹಾಲು ಕುಡಿಯುತ್ತಿದೆ.
18. ಅವಳು ಕಾಗದವನ್ನು ಕತ್ತರಿಸುತ್ತಿದ್ದೆ.
19. ಅದು ಚೆಂಡಿನಿಂದ ಆಡುತ್ತಿದ್ದಾರೆ.
20. ರಾಜು ತಲೆ ಬಾಚಿಕೊಳ್ಳುತ್ತಾ ಇದ್ದಾಳೆ.
21. ನಾನು ನಿನ್ನೆ ಬರುತ್ತೇನೆ.
22. ನನ್ನ ತಂಗಿ ಆಡುತಿದ್ದಾನೆ.
23. ರಸ್ತೆಯಲ್ಲಿ ಬಸ್ಸು ಓಡುತ್ತೇವೆ.
24. ಮರನಲ್ಲಿ ಪಕ್ಷಿಗಳಿವೆ.
25. ನೀರಿದಲ್ಲಿ ಮೀನುಗಳಿವೆ.
26. ಗಾಳಿಪಟಗಳನ್ನು ಹಾರುತ್ತಾರೆ.
27. ಮಕ್ಕಳು ಹಾಲು ಕುಡಿಯು.
28. ನದಿಗಳು ಹರಿಯುತ್ತದೆ.

29. ಹುಡುಗಿ ನಗುತ್ತಿದ್ದಾನೆ.
30. ಮಕ್ಕಳು ಓಡುತ್ತಿದ್ದಾನೆ.
31. ಹುಡುಗರು ಓಡುತ್ತಿದ್ದಾಳೆ.
32. ನಾಯಿಗಳು ಬೋಗಳುತ್ತಿದೆ.
33. ಹಕ್ಕಿಗಳು ಹಾರುತ್ತಿದ್ದಾನೆ.
34. ಮೀನು ಈಜುತ್ತಿದ್ದಾರೆ.
35. ಹೂವು ಅರಳುತ್ತಿದ್ದಾಳೆ.
36. ಶಿಕ್ಷಕಿ ಪಾಠ ಮಾಡುತ್ತಿದೆ.
37. ಮರ ನೆರಳನ್ನು ನೀಡುತ್ತಿದ್ದಾರೆ.
38. ಹುಡುಗಿ ಹಾಡು ಹೇಳುತ್ತಿವೆ.
39. ನೀರು ಹರಿಯುತ್ತಿದ್ದಾನೆ.
40. ಗಾಳಿ ಬೀಸುತ್ತಿದ್ದಾಳೆ.
41. ದೋಣಿ ಸಾಗುತ್ತಿದ್ದಾರೆ.
42. ಅಪ್ಪ ರಸ್ತೆಯಲ್ಲಿ ಬರುತ್ತಿದೆ.
43. ಸ್ನೇಹಿತರು ಮಾತನಾಡುತ್ತಿವೆ.
44. ಪ್ರಕೃತಿ ಸುಂದರವಾಗಿವೆ.
45. ಹಡಗು ಮುಳುಗುತ್ತಿದ್ದಾನೆ.
46. ಕಲಾವಿದ ಚಿತ್ರ ಬರೆಯುತ್ತಿದೆ.
47. ಹುಲಿಗಳು ಮಲಗಿದ್ದಾನೆ.
48. ಬೀಗ ಬಾಗಿಲುಗಳನ್ನು ತೆಗೆಯುತ್ತಿವೆ.
49. ಮಳೆ ಬರುತ್ತಿದ್ದಾಳೆ.
50. ನನಗೆ ಸಂತೋಷವಾಗುತ್ತಿವೆ.

## Appendix-C

## Verbatim instructions given to the participants in neurophysiology lab

Dear Sir,

*Instrucions for placing the electrode cap*

- I am going to place the elctrode cap on your head.
- I will be placing a gel substance to get good contact between electrodes and your scalp.
- This gel does not harm your scalp or skin. I will be cleaning your scalp after completing the task.
- Please sit comfortably and don't make any physical movements of hands or legs during the test procedure.
- The test will take approximately two hours. You will be given a break in between.
- Please let me know if you feel uncomfortable at any point of time during the task.

*Instructions for the task*

- Now I will be presenting few sentences in Kannda and English.
- In first task, I will be presenting 100 sentences on the computer screen and you need to silently read the sentence and decide whether the sentence is correct in meaning.
- If the sentence is meaningful, press the Key-1 on response pad and if the sentence is incorrect in meaning, press the key-2 on response pad with either of the hands as early as possible.
- In the second task, I will be presenting 100 sentences on the computer screen and you need to silently read the sentence and decide whether the sentence is correct in grammar.
- If the sentence is grammatcially correct, press the Key-1 on response pad and if the sentence is grammatically incorrect, press the key-2 on response pad with either of the hands as early as possible.
- I will give four practice items for each task. Please try to do the tasks.
- Do you have any doubts?
- Shall I start the test?